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Baseline Physical, Biological and Chemical Parameters of 21 Lakes, Togiak National Wildlife Refuge, 1984 - 1990

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Baseline Physical, Biological and Chemical Parameters of 21 Lakes, Togiak National Wildlife Refuge, 1984 - 1990

ABSTRACT - Baseline physical, biological, and chemical parameters of 21 lakes located on the Togiak National Wildlife Refuge were measured from 1984 to 1990. In 1984, 17 lakes were surveyed during two flights. In 1986, 9 lakes were surveyed on an opportunistic basis. From 1987 to 1990, the lake survey crew surveyed 16 lakes.

A recording fathometer was used to create a bathymetric map of most lakes. Widths and discharges of lake inlets and outlet rivers were determined. Shoreline substrate and land characteristics of most lakes were documented. The following water quality measurements were taken: temperature, pH, dissolved oxygen, conductivity, secchi disc visibility, acidity, alkalinity, carbon dioxide, and hardness. Resident and anadromous fish species and plankton species and abundance were documented. Important sockeye salmon spawning areas were determined.

Recommendations include future studies that should seek to fill in gaps in the data; to intensify fishery, insect, and plankton density and abundance sampling; quantifying the habitats available for spawning and rearing of the various species present; additional and more detailed sonar transects at the three larger lakes (Togiak, Goodnews and Kanektok) to determine the length of shelves or submerged islands that were noted on the marked transects; quantifying numbers of sockeye salmon spawning in particular areas of the lakes; conducting surveys on major tributaries into the lakes; determining the density of redds; scale pattern analysis to establish stock separation in the system; growth of juveniles; size structure of smolts in the lake and tributaries; and lake productivity.

INTRODUCTION

The Togiak National Wildlife Refuge has numerous lakes which are important to sockeye salmon *Oncorhynchus nerka*, king salmon *Oncorhynchus tshawytscha*, coho salmon *Oncorhynchus kisutch*, rainbow trout *Oncorhynchus mykiss*, lake trout *Salvelinus namaycush*, char *Salvelinus* spp., Arctic grayling *Thymallus arcticus*, whitefish *Coregonus* spp., northern pike *Esox lucius*, sculpin *Cottus* spp., threespine stickleback *Gasterosteus aculeatus* and ninespine stickleback *Pungitius pungitius*. Very little is known of these lakes' morphology, chemistry, present and/or historical fish populations and areas used for spawning.

The objectives of this study were to:

1. Create bathymetric maps of major lakes on the Togiak National Wildlife Refuge;

2. Determine important spawning areas of lakes for sockeye salmon;

3. Document the shoreline substrate and land characteristics;

4. Collect water quality data on major lakes on the Togiak Refuge;

5. Measure the discharge of water from each lake into their respective rivers;

6. Determine the occurrence and age, weight, and length of fish species in Refuge lakes; and

7. Collect plankton samples from Refuge lakes to establish preliminary information on production.

This report summarizes the data collected over six years to make it available for resource managers and biologists. A brief narrative description of each lake's characteristics and what was found there is provided. Measured values and calculations are summarized in the tables that follow. More detailed information (e.g. water quality profiles, shoreline substrate) are not provided in this report, but can be made available upon request.

METHODS

Refuge personnel collected inventory and baseline data in 21 Togiak Refuge lakes from 1984 to 1990. Lake survey sampling began with a preliminary survey in 1984 (17 lakes), followed by sampling in 1986 (9 lakes), 1987 (7 lakes), 1988 (8 lakes), 1989 (1 lake), and 1990 (1 lake). The surveys conducted in 1984 consisted of taking temperature and chemical profiles from each lake while standing on the floats of an airplane. In the following years, more intensive surveys and lake mapping was conducted by a crew of at least two technicians using inflatable rafts.

Bathymetric Mapping

Bathymetric data was collected using a Lowrance Eagle Mach I ™ chart recording fathometer and making constant soundings between transect end points (Lind 1979). Transects were made along the central axis (longest straight distance) and perpendicular to this axis between landmarks. Each transect was marked on an enlarged copy of the lake from a U.S. Geological Survey topographic map. Aerial photographs were sometimes used when they were available and found to be more accurate than the topographic maps. Natural landmarks, such as points, islands, and stream inlets, were used to locate transects. Transects were run only in relatively calm weather. Lake profile information was transferred to lake maps and contour intervals of 5', 10', or 20' were connected to make bathymetric maps which are included as Appendices.

Lake area was calculated on the bathymetric maps with a Lietz™ compensating polar planimeter. The volume of each lake was calculated by formula as in Lind (1979):

$$V = \frac{h}{3}(a_1 + a_2 + \sqrt{a_1 a_2})$$

where: h = depth of conical segment
a_1 = area of segment's surface
a_2 = area of segment's bottom

This volume calculation determines and then sums the volumes of conical segments, with upper and lower surfaces delimited by the areas of sequential depth contours.

Shoreline development (an index of the regularity of the shoreline) was calculated as described in Lind (1979):

$$SLD = \frac{S}{2\sqrt{a\pi}}$$

where: S = length of shoreline
a = area of lake

Spawning Areas

Surveys of sockeye salmon spawning activity, or redds, by observation were attempted periodically during the late summer season by motoring around the perimeter of the lake and observing the fish. Depth and substrate type at areas of activity were recorded (as outlined in next methods subsection). If fish were not detected, redds were documented.

Sockeye salmon spawning areas appeared as darkened spots where apparent fanning and removal of silt occurred. These areas contrasted greatly to surrounding lighter colored, silt covered gravel.

Shoreline substrate and land characteristics

The land characteristics surrounding each lake and the bottom composition and habitat of the lake's near shore area was recorded and marked on a map of the lake. The substrate size of the lake's near shore area was recorded using the following bottom type breakdown:

1 = mud
2 = sand
3 = medium boulders

4 = small boulders
5 = large cobble
6 = small cobble
7 = very coarse gravel
8 = coarse gravel
17 = coarse silt
19 = fine silt

Maps created by these observations are not included in this report. A narrative description is included for each lake in the results section.

Water Quality of Major Lakes

Water quality, including temperature, dissolved oxygen, conductivity, pH, secchi disk visibility, acidity, alkalinity, carbon dioxide, and hardness were measured at three sites per lake using a Hydrolab™ 4041 Water Quality Measurement System and a HACH Water Ecology Kit, Model AL-36B. The three sites per lake included the inlet area, middle of the lake, and the outlet area.

Profiles of temperature, pH, conductivity and dissolved oxygen were measured with the Hydrolab from the surface and 1 m to 10 m intervals to the lake bottom or to a maximum depth of 50 m. The Hydrolab was recalibrated between testing of each lake. Alkalinity, acidity, carbon dioxide, and hardness were measured using the HACH kit. A 1 liter sample of lake surface water was collected at each site and tested within 4 hours of retrieval. Secchi disk visibility depth was measured by submerging the disk until it was no longer visible to an observer wearing polarized sunglasses and then raising it until it was sighted again.

Mean water quality measurements listed in Table 2 were calculated by averaging each parameter from the surface to the bottom.

Stream Discharge

Streamflow and discharge were measured at inlet and outlet streams using a Price AA current meter following procedures in the Stream Discharge Measurement Handbook (USFWS 1988). Only those streams and rivers which could be walked were measured. All data was recorded on the U.S. Geological Survey Discharge Measurement Notes, Form 9-275-F (Appendix A).

Age, Weight, and Length of Fish Species

Gill nets, seines, minnow traps, and rod and reel techniques were employed in all areas of the lake to capture fish. Spawned out salmon found along the lake shore were also included in the

sample. All species captured were cataloged for location of collection, method of capture, length, weight, stomach contents, and sex. Gill nets were set to avoid sockeye salmon concentrations. The nets were fished at varying depths and lengths of time. Salmon eggs, viscera or stomach contents were used to bait the minnow traps. The total hours fished and species captured was recorded for each gear type.

Stomach content items were identified and counted. Fish and insects found in the stomachs were keyed out to family or species back in the lab.

Captured fish were measured using standard age, weight, and length (AWL) sampling as outlined in Clutter and Whitesel (1956). Fork length was recorded for the resident species to the nearest millimeter. Mid-eye to fork length was recorded for adult salmon to the nearest millimeter.

Data was analyzed using a crosstabulation program called BBX, developed by the Alaska Department of Fish and Game Research and Technical Services (Heineman 1989). The BBX program produces unweighted estimates of mean length and percentage by age group and the associated standard error estimates following procedures outlined by Sokal and Rohlf (1981, Boxes 4.2 and 7.1, pages 56 and 139) (Riffe 1994). Summary tables produced by the BBX program are presented in the results as Table 5.

All char mortalities were dissected to determine species using criteria as described by Morrow (1980). The number of gill rakers and pyloric caeca were counted to determine whether the fish were Dolly Varden or Arctic char. Fish were classified as Arctic char if they had 23 to 32 gill rakers on the first gill arch and 35 to 75 pyloric caeca or as Dolly Varden if they had 11 to 26 gill rakers and 13 to 35 pyloric caeca.

Plankton Sampling

Plankton samples were collected at the time water quality measurements were taken and within the same vicinity. Forty-five foot vertical plankton tows were pulled using a standard Wisconsin plankton net with a 153 microscreen opening (Lind 1979). Shorter or longer tows were taken depending on water depth. The net was raised using a steady, quick, retrieve. The contents were rinsed into a 150 ml plastic bottle. Each sample was labeled with the date and location. All samples were preserved in a 1% formalin solution and dyed with bengal red. Collections were examined under microscope to determine families of zooplankton present (Pennak 1989).

The number of organisms per milliliter of concentrate (O_X) was calculated using the aliquot method (Lind 1979). The number of organisms per liter of lake water (O_L) was determined by:

$$O_L = \frac{O_X \; x \; 1000 \; ml}{[C]}$$

$$[C] = \frac{V_{tow} \quad (\pi r^2 h)}{V_{concentrate}}$$

RESULTS

Amanka Lake is the headwaters of the Igushik River which flows into Nushagak Bay on the southeastern side of the refuge (Figure 1). Amanka Lake lies in an east - west direction and has six inlet streams. The outlet is located at the south corner of the lake. The lake's length, width, surface area, elevation, and maximum depth are given in Table 1. Amanka Lake was studied in 1984 during a preliminary study and only water quality data was taken. No physical or biological samples were collected. Although a spawning survey of sockeye salmon was not undertaken, the Togiak Refuge Fisheries Management Plan (USFWS 1990) states that the Amanka Lake tributaries Francis Creek and the Ongoke River are important sockeye salmon spawning areas.

Water quality was measured at one site at varied intervals down to 23 m on 6 June 1984. Mean water quality parameters are presented in Table 2.

Arolik Lake is the headwaters of the East Fork of the Arolik River which flows into Kuskokwim Bay on the northwestern side of the refuge (Figure 1). Arolik Lake lies in a northwest - southeast direction and has one inlet stream. The outlet is located at the northwest corner of the lake. The lake's length, width, surface area, elevation, and maximum depth are given in Table 1. The width and discharge of the inlet and outlet of Arolik Lake is shown in Table 3. A bathymetric map of Arolik Lake is included as Appendix B1.

The beach around the lake in 0 to 1.8 m wide and consists of small gravel to large boulders with an abundance of fine gravel at the lake's outlet and nearby shore. The majority of Arolik Lake's shoreline drops off abruptly with a bottom substrate comprised of sand, cobble, and rocks. No emergent or submergent vegetation was noted. Mountains rise sharply along both sides of Arolik Lake with large gravel slides down to the water. The northwest and southeast ends of the lake open up to wide expanses of wet rolling tundra with dispersed patches of willows and alders. The southeast shore, near the lake's inlet, is a spawning area which contains small gravel and has small sockeye salmon concentrations near shore.

Water quality was measured at one site at varied intervals down to 23 m on 6 June 1984 and at the surface at three sites on 28 August 1988. Mean water quality parameters are presented in Table 2.

Gill net sampling caught lake trout and whitefish (Table 4). Lake trout averaged 400 mm in length and 862 g in weight (Table 5). Sex was determined from 6 lake trout. The single

whitefish got away before any measurements could be taken. The stomach contents of 6 lake trout were documented and consisted of insects, mollusks, and fish remains (Table 6). No plankton sampling was conducted in Arolik Lake.

Canyon Lake is the headwaters of Canyon Creek which flows into the North Fork of the Goodnews River on the western side of the refuge (Figure 1). Canyon Lake lies in a northwest - southeast direction and has one inlet stream. The outlet is located at the southeast corner of the lake. The lake's length, width, surface area, elevation, and maximum depth are given in Table 1. The width and discharge of the inlet and outlet of Canyon Lake is shown in Table 3. A bathymetric map of Canyon Lake is included as Appendix B2.

The shoreline drops off gradually around the entire lake and has little shoal area. The east and west shores are shallow with sand and large gravel beaches, while the north and south shoreline are silty mud with large cobble and boulders. Virtually no beach can be found along the north and south sides as they are lined with large rocks and alders. Steep, rocky mountains rise directly off the lake except at the inlet and outlet where there is rolling tundra. Vegetation varies from open tundra to alder and willow lined shoreline. No emergent or submergent vegetation are present at Canyon Lake. Grasses, sedges, muskeg, fireweed, cottongrass, blueberries, monkshood, river beauty, yarrow, cow parsnip, and others make up the terrestrial vegetation.

Water quality was measured at one site at varied intervals down to 23 m on 6 June 1984 and at the surface at three sites on 25 August 1988. Mean water quality parameters are presented in Table 2.

Hook and line sampling caught char and lake trout, gill net sampling caught char, lake trout and sockeye salmon, and minnow trap sampling caught coho salmon, chinook salmon, sculpin, and sockeye salmon (Table 4). These char averaged 437 mm in length and 879 g in weight (Table 5). These lake trout averaged 471 mm in length and 1190 g in weight. Sex was determined from 15 char and from 1 lake trout. Large sockeye salmon concentrations were observed around the entire perimeter of the lake. The inlet and lake shoal area have gravel suitable for spawning. No plankton sampling was conducted in Canyon Lake.

Gechiak Lake is the headwaters of Gechiak Creek which flows into the Togiak River on the southern side of the refuge (Figure 1). Gechiak Lake lies in a northwest - southeast direction and has two inlet streams. The outlet is located at the southeast corner of the lake. The lake's length, width, surface area, elevation, and maximum depth are given in Table 1. The width and discharge of the two inlets into Gechiak Lake is shown in Table 3. A bathymetric map of Gechiak Lake is included as Appendix B3.

The shoreline of Gechiak Lake is comprised of shallow to gradual dropoffs and is primarily sand, large gravel, and rocks along the eastern and western sides. The beach around the lake ranges from 0 to 1.8 m in width and varies from gravel bars to large rocks to alder-lined shores. Small tufts of submergent grass are present on the west side. Mountains rise gradually off the lake to

the east and west. Open tundra is to the north and south around the inlets and outlet. Alders, grasses, sedges, willows, fireweed, blueberries, cow parsnip, and others make up the terrestrial vegetation.

Water quality was measured at one site at varied intervals down to 23 m on 6 June 1984, at intervals down to 49 m at one site on 30 October 1986, and at the surface at three sites on 20 August 1988. Mean water quality parameters are presented in Table 2.

Hook and line sampling caught char and rainbow trout, gill net sampling caught char, chinook salmon, and sockeye salmon, and minnow trap sampling caught coho salmon and sticklebacks (Table 4). These char averaged 427 mm in length and 851 g in weight (Table 5). Sex was determined from 19 char. The rainbow trout, chinook salmon and sockeye salmon were not measured. Sockeye salmon were observed around the entire lake.

From a single foot plankton tow, 35 individual organisms representing 5 species were found to be present (Table 7).

Goodnews Lake is the headwaters of the North Fork of the Goodnews River which flows into Kuskokwim Bay on the western side of the refuge (Figure 1). Goodnews Lake lies in a northeast - southwest direction and has five inlet streams. The outlet is located at the southwest corner of the lake. The lake's length, width, surface area, elevation, and maximum depth are given in Table 1. The smaller lake located below Goodnews Lake had a maximum depth of 43 feet. There were no stream discharge measurements taken on Goodnews Lake. A bathymetric map of Goodnews Lake is included as Appendix B4.

The bottom contour of Goodnews Lake is sharp dropoffs to 96 m with a more gradual decline to 160 m. There are wide shallow shelves approximately 5 m deep along the shore in the northern corner of the lake. There lake has about 10% shoal area. The inlet, outlet, narrows, and much of the shoal area of the lake have an abundance of fine and medium gravel. The southwest section of the lake below the narrows is shallow with gravel and silt bottom covered with algae. The terrain surrounding Goodnews Lake consists of tundra, dwarf willow and alder, and an occasional stand of cottonwood trees.

Water quality was measured at one site at varied intervals down to 23 m on 6 June 1984 and at 5 sites at intervals down to 30 m on 20 July and 30 October 1986. Mean water quality parameters are presented in Table 2.

Hook and line sampling in Goodnews Lake caught char and lake trout (Table 4). These char averaged 536 mm in length (Table 5). The lake trout averaged 504 mm in length. Weights were not taken on these fish and the sex was not determined. Goodnews Lake was not surveyed for spawning habitat, however, the lake does provide valuable spawning habitat for salmon.

From five plankton tows made on Goodnews Lake, 276 individual organisms representing 6

species were found to be present (Table 7).

Heart Lake is the headwaters of Milk Creek which drains into Chikuminuk Lake outside of the refuge to the northeast (Figure 1). Heart Lake lies in an east - west direction and has one inlet stream. The outlet is located at the east side of the lake. The lake's length, width, surface area, elevation, and maximum depth are given in Table 1. The width and discharge of the outlet of Heart Lake is shown in Table 3. A bathymetric map of Heart Lake is included as Appendix B5.

An in depth shoreline and land characteristic survey was not performed at Heart Lake. The whole shoreline was primarily mixed small cobble, large cobble, and very coarse gravel.

Water quality was measured at one site at varied intervals down to 23 m on 6 June 1984 and six sites at intervals down to 35 m on 13 July 1987. Mean water quality parameters are presented in Table 2.

Hook and line sampling caught char and lake trout, gill net sampling caught char and lake trout, and minnow trap sampling caught lake trout and sculpin (Table 4). These char averaged 418 mm in length and 1,034 g in weight (Table 5). These lake trout averaged 457 mm in length and 1,200 g in weight. Char had an average of 46 pyloric caeca and 24 gill rakers (Table 8). These fish are classified as Arctic char. Sex was determined from 14 char and from 20 lake trout. The stomach contents of 14 char and 20 lake trout were documented and consisted of insects, mollusks, fish remains, and other components (Table 6). Spawning area data was not collected from Heart Lake.

From three plankton tows made on Heart Lake, 4,086 individual organisms representing 5 species were estimated to be present (Table 7).

High Lake is the headwaters of an unnamed tributary that flows into Trail Creek. Trail Creek drains into the Izavieknik River upstream of Togiak Lake on the eastern side of the refuge (Figure 1). High Lake lies in a northeast - southwest direction and has two inlet streams. The outlet is located at the southwest corner of the lake. The lake's length, width, surface area, elevation, and maximum depth are given in Table 1. The width and discharge of the inlet and outlet of High Lake is shown in Table 3. A bathymetric map of High Lake is included as Appendix B6.

An in depth shoreline and land characteristic survey was not performed for High Lake. The lake shore substrate is made up of various size gravel, cobble, and boulders with small to large cobble predominating. The shoal area is limited.

Water quality was measured at one site at varied intervals down to 23 m on 4 June 1984 and at four sites at intervals down to 50 m on 13 July 1987. Mean water quality parameters are presented in Table 2.

Gill net and minnow trap sampling caught char and whitefish (Table 4). These char averaged 327 mm in length and 351 g in weight (Table 5). The whitefish were not measured. Char had an average of 30 pyloric caeca and 22 gill rakers (Table 8). These fish are classified as Dolly Varden. Sex was determined from 21 char. The stomach contents of 21 char were documented which consisted of insects, mollusks, and fish remains (Table 6). Spawning area data was not collected from High Lake.

From three plankton tows, 625 individual organisms representing 5 species were found to be present (Table 7).

Kagati Lake is the headwaters of the Kanektok River which flows into Kuskokwim Bay on the northwestern side of the refuge (Figure 1). Kagati Lake lies in a northwest - southeast direction and has four inlet streams. The outlet is located at the west corner of the lake. Kagati Lake has two arms, Kagati Arm to the northeast and Pegati Arm to the southwest. The lake's length, width, surface area, elevation, and maximum depth are given in Table 1. There were no stream discharge measurements taken on Kagati Lake. A bathymetric map of Kagati Lake is included as Appendix B7.

The two arms have dissimilar bottom contours. Kagati Arm consists of steep dropoffs along each shore and becomes gradually shallower towards the inlet at the upper end of the lake. Pegati Arm has steep dropoffs along the south shore while the north shore has an irregular bottom pattern and was much shallower. The lake shore is comprised of fine to medium gravel and some large rubble which quickly grades to large gravel and rubble. There is very little shoal area. The area surrounding Kagati Lake is composed primarily of rolling tundra and thick patches of dwarf willow.

Water quality was measured at two sites at varied intervals down to 23 m on 4 June 1984, at four sites down to 50 m on 30 June and 30 October 1986, at one site at 5 m intervals down to 10 m on 22 October 1987, and at eight sites at intervals down to 35 m on eight different days in 1989. Mean water quality parameters are presented in Table 2.

A field crew collected lake trout data in Kagati Lake from 1988 to 1990 (MacDonald and Lisac, in prep.). Sampling occurred from 7 - 28 July in 1988, 25 June - 22 August in 1989, and from 18 June - 3 September 1990. During this lake trout study, 758 lake trout were sampled using rod and reel. The lake trout averaged 423 mm in length and 658 g in weight (Table 5). Sex was determined from 34 lake trout. Ages were determined from 35 mortalities and ranged from ages 6 to 26. The stomach contents of 22 lake trout were documented which consisted of insects, mollusks, fish remains, and other components (Table 6).

In addition, hook and line sampling produced char, coho salmon, and sockeye salmon, gill net sampling caught char, sockeye salmon, and whitefish, minnow traps caught char and coho salmon and 239 dead, spawned out sockeye salmon were sampled. These char averaged 508 mm in length and 2,339 g in weight (Table 5). The whitefish averaged 420 mm in length. The coho

salmon averaged 833 mm in length. The sockeye salmon averaged 513 mm in length. Sex was determined from 6 coho salmon and 239 sockeye salmon. No sex determination was made for the char and whitefish sampled. Spawning areas were not documented at Kagati Lake, although Kagati Lake provides valuable spawning habitat for salmon.

From twenty-two plankton tows, 4,127 individual organisms representing 7 species were found to be present (Table 7).

Kanuktik Lake is the headwaters of Kanuktik Creek which flows into the Kanektok River on the northwestern side of the refuge (Figure 1). Kanuktik Lake lies in a north northwest - south southeast direction and has one inlet stream. The outlet is located at the north northwest corner of the lake. The lake's length, width, surface area, elevation, and maximum depth are given in Table 1. The width and discharge of the inlet of Kanuktik Lake is shown in Table 3. A bathymetric map of Kanuktik Lake is included as Appendix B8.

Kanuktik Lake drops off abruptly from the shore. Dropoffs consist of extremely large boulders, rock, silty sand, and small to medium gravel. Shoal area near the inlets have a bottom composed of fine sand and gravel while the outlet shoal contained fine gravel mixed with boulders. The narrow shoreline is large rocks and boulders with a few gravel beaches. Many tributaries feed the lake from the mountain sides which rise gradually off the lake edge and have a combination of rocky and vegetated slopes. There is little to no emergent or submergent vegetation. The dominant vegetation is alder and open tundra with low scrub willows lining most tributaries and few cottonwood trees. Blueberries, salmon berries, crowberries, fireweed, dwarf fireweed, king's crown, wormwood, dogwood, cow parsnip, and mushrooms are also present.

Water quality was measured at one site at varied intervals down to 23 m on 4 June 1984, one site at intervals down to 40 m on 30 October 1986, and at the surface at three sites on 3 August 1988. Mean water quality parameters are presented in Table 2.

Hook and line sampling caught lake trout, gill net sampling caught char and lake trout, and minnow traps caught no fish (Table 4). Lake trout averaged 457 mm in length and 1,233 g in weight (Table 5). Char averaged 490 mm in length and 1,429 g in weight. Sex was determined from 6 char and 5 lake trout. Spawning area data was not collected from Kanuktik Lake.

From one plankton tow, 61 individual organisms representing 4 species were found to be present (Table 7).

Klak Lake is the headwaters of Klak Creek which flows into the Kanektok River on the northwestern side of the refuge (Figure 1). Klak Lake lies in a northwest - southeast direction and has two inlet streams. The outlet is located at the south corner of the lake. The lake's length, width, surface area, elevation, and maximum depth are given in Table 1. Fish species, plankton species, stream discharge measurements, sonar mapping, shoreline substrate and land characteristics were not documented for Klak Lake.

The lake has little shoal area and is generally covered with boulders and an overlay of silt. Shoreline vegetation is willow and open tundra. The rocks in the outlet stream were covered with algae and most gravel that would be suitable for spawning is located at the lake's outlet and two major inlets.

Water quality was measured at one site at varied intervals down to 23 m on 4 June 1984. Mean water quality parameters are presented in Table 2.

Kukaktlim Lake is the headwaters of the Kukaktlik River which flows into the Middle Fork of the Goodnews River on the western side of the refuge (Figure 1). Kukaktlim Lake lies in a northeast - southwest direction and has one inlet stream. The outlet is located at the southwest corner of the lake. The lake's length, width, surface area, elevation, and maximum depth are given in Table 1. Fish species, plankton species, stream discharge measurements, sonar mapping, shoreline substrate and land characteristics were not documented for Klak Lake. The lake appears to have good spawning gravel.

Water quality was measured at one site at intervals down to 3.5 m on 6 June 1984. Mean water quality parameters are presented in Table 2.

Kulukak Lake is the headwaters of the Kulukak River which flows into Kulukak Bay on the southeastern side of the refuge (Figure 1). Kulukak Lake lies in a northeast - southwest direction and has two inlet streams. The outlet is located at the southwest corner of the lake. The lake's length, width, surface area, elevation, and maximum depth are given in Table 1. The width and discharge of the inlet and outlet of the lake is shown in Table 3. A bathymetric map of Kulukak Lake is included as Appendix B9.

Shorelines drop off abruptly around the majority of the lake's perimeter. The shoreline is mostly rocky, with gravel, sand, and mud bottom. Very few emergent or submergent vegetation are present. The terrain surrounding Kulukak Lake is hilly and mountainous with rolling tundra. The primary vegetation around the lake is alder, sedges, willows, and cottonwood.

Water quality was measured at one site at varied intervals down to 15 m on 6 June 1984 and at three sites at intervals down to 17 m on 24 July 1988. Mean water quality parameters are presented in Table 2.

Hook and line sampling caught char, gill net sampling caught char, sockeye salmon, and whitefish, and minnow traps caught char, coho salmon, chinook salmon, sculpin, and sockeye salmon (Table 4). These char averaged 255 mm in length and 325 g in weight (Table 5). The whitefish averaged 137 mm in length and 19 g in weight. The sockeye salmon were not measured. Sex was determined from 24 char and from 18 whitefish. Many sockeye salmon were observed, especially along the northeastern shoreline. No plankton sampling was conducted.

Nagugun Lake is the headwaters of the Nayorurun River which drains into the Togiak River on

the southern side of the refuge (Figure 1). Nagugun Lake lies in a northwest - southeast direction and has no inlet streams. The outlet is located at the southeast corner of the lake. The lake's length, width, surface area, elevation, and maximum depth are given in Table 1. The width and discharge of the outlet of Nagugun Lake is shown in Table 3. A bathymetric map of Nagugun Lake is included as Appendix B10.

Nagugun Lake has dispersed gravel beaches varying to large rocks and boulders. Large rock outcroppings are at the outlet, northeast, and west sides of the lake. The southern portion of Nagugun Lake has gradual to sharp dropoffs, with much of the narrow shoreline comprised of large gravel, rocks, and boulders. Mountains surround the lake beginning from gradual to steep inclines, producing many high mountain streams which run into the lake. Little to no emergent or submergent vegetation are present. Open, dry tundra and sedges with patches of alder, willow and cottonwood are the dominant vegetation. Flowering species include fireweed, dwarf fireweed, mountain laurel, dogwood, cow parsnip, lousewort, bistort, king's crown, cottongrass, blueberries, crowberries, and mushrooms.

Water quality was measured at one site at varied intervals down to 20 m on 4 June 1984, at one site down to 50 m on 30 October 1986, and at the surface at three sites on 29 July 1988. Mean water quality parameters are presented in Table 2.

Hook and line sampling caught char, gill net sampling caught char, minnow traps caught chinook salmon and sculpin, and char were handpicked and sampled (Table 4). These char averaged 350 mm in length and 462 g in weight (Table 5). Whitefish averaged 137 mm in length and 19 g in weight. Sex was determined from 46 char and from 4 whitefish. Spawning areas were not documented in Nagugun Lake.

From one plankton tow, 208 individual organisms representing 6 species were found to be present (Table 7).

Nenevok Lake is the headwaters of the Kemuk River which flows into the Togiak River on the southern side of the refuge (Figure 1). Nenevok Lake lies in a northwest - southeast direction and has four inlet streams. The outlet is located at the southwest corner of the lake. The lake's length, width, surface area, elevation, and maximum depth are given in Table 1. Stream discharge measurements were not taken on Nenevok Lake. A bathymetric map of Nenevok Lake is included as Appendix B11.

An in depth shoreline and land characteristic survey of Nenevok Lake was not performed. The northeast shore of the lake is very coarse gravel. The rest of the lake is made up of small boulders, small to large cobble, coarse to very coarse gravel, and coarse silt.

Water quality was measured at one site at varied intervals down to 50 m on 30 October 1986 and five sites down to 35 m on 8 July 1987. Mean water quality parameters are presented in Table 2.

Gill net sampling caught char and lake trout and minnow traps caught char, lake trout, and sculpin (Table 4). The char averaged 426 mm in length and 1,036 g in weight (Table 5). The lake trout averaged 533 mm in length and 1,713 g in weight. Sex was determined from 7 char and from 2 lake trout. Spawning areas were not documented in Nenevok Lake.

From four plankton tows, 1,059 individual organisms representing 6 species were found to be present (Table 7).

Ohnlik Lake is the headwaters of Kanuktik Creek which flows into the Kanektok River on the northwestern side of the refuge (Figure 1). Ohnlik Lake lies in a north northwest - south southeast direction and has one inlet stream. The outlet is located at the northwest corner of the lake. The lake's length, width, surface area, elevation, and maximum depth are given in Table 1. The width and discharge of the inlet and outlet of Ohnlik Lake is shown in Table 3. A bathymetric map of Ohnlik Lake is included as Appendix B12.

Ohnlik Lake has varying sharp dropoffs, shallow pools, and gradual slopes. Bottom substrates vary from sand to small cobble to silty mud and large rocks. The surrounding mountains rise gradually off the lake with the south end of the lake an open valley. There is no emergent or submergent vegetation. Shoreline vegetation is either open tundra, alders, or small willows with a few scattered cottonwood stands. Fireweed, dwarf fireweed, and blueberries are also present.

Water quality was measured at the surface at three sites on 7 August 1988. Mean water quality parameters are presented in Table 2.

Hook and line sampling caught char and lake trout, gill net sampling caught lake trout, and minnow traps caught coho salmon and sockeye salmon (Table 4). These char averaged 472 mm in length and 1,110 g in weight (Table 5). The lake trout averaged 410 mm in length and 732 g in weight. Sex was determined from 4 lake trout. There were small concentrations of sockeye salmon in the northeast end near the tributaries. The lake has three major inlets which provide the main spawning habitat. No plankton information was collected.

Ongivinuck Lake is the headwaters of the Ongivinuck River which flows into the Togiak River on the southern side of the refuge (Figure 1). Ongivinuck Lake lies in a east northeast - west southwest direction and has one inlet stream. The outlet is located at the west corner of the lake. The lake's length, width, surface area, elevation, and maximum depth are given in Table 1. The width and discharge of the inlets and outlet of Ongivinuck Lake is shown in Table 3. A bathymetric map of Ongivinuck Lake is included as Appendix B13.

An in depth substrate and land characteristic survey was not done for Ongivinuck Lake. The lake shoreline is primarily fine silt with medium to very coarse gravel. Medium and small cobble is present in places also. The lake bottom along the east shore and occasionally other areas was moss covered. There is approximately 10 to 20% shoal area present.

Water quality was measured at four sites at 1 m intervals down to 10 m on 10 August 1987. Mean water quality parameters are presented in Table 2.

Hook and line sampling caught char, gill net sampling caught char, Arctic grayling, sockeye salmon, and whitefish, and minnow traps caught char, chinook salmon, and sticklebacks (Table 4). These char averaged 382 mm in length and 668 g in weight (Table 5). The single grayling was 253 mm long and 225 g in weight. The whitefish averaged 328 mm in length and 392 g in weight. The sockeye salmon were not measured. Sex was determined from 20 char, 1 grayling, and 3 whitefish. Sockeye salmon were observed spawning along the whole north shore of Ongivinuck Lake and part of the southwest shore. The moss covered east shore was not suitable for spawning. The south shore was possible spawning substrate but no actual spawning was observed. The hook and line and gill net sampled char had an average of 49 pyloric caeca and 22 gill rakers (Table 8). These fish are classified as Arctic char. The stomach contents of 20 char were documented which consisted of insects, mollusks, and fish remains (Table 6).

From three plankton tows, 1,710 individual organisms representing 6 species were found to be present (Table 7).

Pungokepuk Lake is the headwaters of Pungokepuk Creek which flows into the Togiak River (Figure 1). The lake is oriented in a northeast to southwest direction. The lake has two inlet streams and flows out from the southwest end. Pungokepuk Lake is very convoluted and contains many shallow, weedy bays. The lake's length, width, surface area, elevation, and maximum depth are given in Table 1. The width and discharge of the inlet of the lake is shown in Table 3. A bathymetric map of Pungokepuk Lake is included as Appendix B14.

The lake bottom is small rocks, weeds, algae, sand, and gravel. Shoals drop off to dark mucky algae and tall submergent vegetation. The lake is rocky around points. There is about 30% shoal area. The land surrounding Pungokepuk Lake is open tundra, with berry bushes, dwarf birch, alder, and low lying grasses with many beaver sloughs.

Water quality was measured at one site at varied intervals down to 15 m on 6 June 1984, at one site down to 8 m on 30 October 1986, and at three sites down to 17 m on 14 July 1988. Mean water quality parameters are presented in Table 2.

Hook and line sampling caught northern pike, rainbow trout, and sockeye salmon, gill net sampling caught pike, rainbow trout, sockeye salmon, and whitefish, and minnow traps caught coho salmon, rainbow trout, sculpin, sockeye salmon, sticklebacks, and unidentified salmon (Table 4). These pike averaged 487 mm in length and 881 g in weight (Table 5). The rainbow trout averaged 574 mm in length and 2,148 g in weight. The whitefish averaged 468 mm in length and 1,245 g in weight. The sockeye salmon averaged 581 mm in length. The grayling was not measured. Sex was determined from 7 rainbow trout, 25 northern pike, 9 sockeye salmon, and from 26 whitefish. Sockeye salmon were observed along the deeper edges of shoals. The bottom composition along the shore is conducive to sockeye salmon spawning.

From one plankton tow, 8 individual organisms representing 4 species were found to be present (Table 7).

Togiak Lake is the headwaters of the Togiak River which flows into Bristol Bay (Figure 1). The lake is oriented in a north-northeast to south-southwest direction. The lake has eight inlet streams and flows out from the southwest end. The lake's length, width, surface area, elevation, and maximum depth are given in Table 1. There were no stream discharge measurements taken on Togiak Lake. A bathymetric map of Togiak Lake is included as Appendix B15.

An in depth survey of shoreline substrate and land characteristics was not made. Togiak Lake is characterized by many sandy beaches and shallow bays, especially along the east shore. There is a variety of substrates, from shallow, muddy sloughs to sheer rocky bottoms.

Water quality was measured at one site at varied intervals down to 20 m on 4 June 1984, and at two sites on 27 August and 30 October 1986. Mean water quality parameters are presented in Table 2.

There was no fishery sampling in Togiak Lake. Togiak Lake is prime habitat for spawning salmon with seven major tributaries flowing into the lake. Sockeye salmon in Togiak Lake appear to prefer substrates of fine gravel as the majority of salmon activity occurred over sand, fine, medium, and course gravel. Little aquatic vegetation was found over these areas. Sockeye salmon were not observed over substrates consisting solely of small cobble or rocks, or sandy bottoms. Depths of active redds ranged from 3 to 11 m of water. Distance to shore from these areas was dependent on water depth. One to two salmon were sometimes observed over these areas, possibly protecting a redd. The east side of Togiak Lake is characterized by many small shallow bays. The greater abundance of salmon activity was found on this shore. The west shore was found to contain fewer areas of suitable substrate and has many narrow shoals and steep dropoffs. Major tributaries flowing into Togiak Lake contain additional spawning potential. Many sockeye salmon were noted over the outlet flume and adjacent gravel of many inlet streams. However, other inlets appeared to have little or no salmon activity. Preference for inlet areas in unknown, but could be affected by such variables as surface flow and water chemistry. Schools of sockeye salmon were also observed at the surface over deeper water. These salmon were possibly in transit to different sections of the lake.

From sixteen plankton tows, 2,424 individual organisms representing 6 species were found to be present (Table 7).

Ualik Lake is part of the headwaters of the Ongoke River which flows into Amanka Lake (Figure 1). The lake is oriented in a northeast to southwest direction. The lake has five inlet streams and flows out from the northeast end. The lake's length, width, surface area, elevation, and maximum depth are given in Table 1. Fish species, plankton species, stream discharge measurements, sonar mapping, spawning areas, shoreline substrate and land characteristics were not documented for Ualik Lake.

Water quality was measured at one site at varied intervals down to 23 m on 6 June 1984. Mean water quality parameters are presented in Table 2.

Upper Togiak Lake is the headwaters of the Izavieknik River which flows into Togiak Lake (Figure 1). The lake is oriented in a north-northeast to south-southwest direction. The lake has three inlet streams and flows out from the southwest end. The lake's length, width, surface area, elevation, and maximum depth are given in Table 1. The widths of stream inlets into Upper Togiak Lake is shown in Table 3. A bathymetric map of Upper Togiak Lake is included as Appendix B16.

An in depth shoreline substrate and land characteristic survey was not done for Upper Togiak Lake. The shoreline around the lake is primarily small cobble and very coarse gravel. Large cobble and very fine gravel was found occasionally around the lake shore.

Water quality was measured at one site at varied intervals down to 25 m on 4 June 1984, at one site down to 50 m on 30 October 1986, and at six sites down to 50 m on 4 August 1987. Mean water quality parameters are presented in Table 2.

Hook and line sampling caught char, gill net sampling caught char, and minnow traps caught char and sculpin (Table 4). These char averaged 332 mm in length and 409 g in weight (Table 5). Sex was determined from 7 char. Spawning areas were not documented in Upper Togiak Lake. The shoal area around the lake provides spawning substrate for sockeye salmon. Char had an average of 42 pyloric caeca and 21 gill rakers (Table 8). These fish are classified as Arctic char.

From four plankton tows, 1,305 individual organisms representing 6 species were found to be present (Table 7).

West Togiak Lake is the headwaters of an unnamed creek that flows into Togiak Lake (Figure 1). The lake is oriented in a north-northeast to south-southwest direction. The lake has one inlet stream and flows out from the south end. The lake's length, width, surface area, elevation, and maximum depth are given in Table 1. Widths of the inlet and outlet of the lake are shown in Table 3. A bathymetric map of West Togiak Lake is included as Appendix B17.

An in depth shoreline substrate and land characteristic survey was not done at West Togiak Lake. The lake's north shore was made up of sand, large cobble, very coarse gravel, and small boulders. The south shore was very grassy with occasional large cobble, small boulders, and very coarse gravel. There is approximately 10% shoal area.

Water quality was measured at five sites at 1 m intervals down to 17 m on 1 July 1987. Mean water quality parameters are presented in Table 2.

Gill net sampling caught char, pike, and whitefish and minnow traps caught char, sculpin, and

sticklebacks (Table 4). These char averaged 417 mm in length and 726 g in weight (Table 5). The whitefish averaged 405 mm in length and 622 g in weight. The single northern pike was not measured. Sex was determined from 3 char and from 9 whitefish. Spawning areas were not documented on West Togiak Lake. The gill net sampled char had an average of 31 pyloric caeca and 22 gill rakers (Table 8). These fish are classified as Dolly Varden. The stomach contents of 23 char were documented which consisted of insects, mollusks, fish remains, and other components (Table 6).

From three plankton tows, 13 individual organisms representing 1 species were found to be present (Table 7).

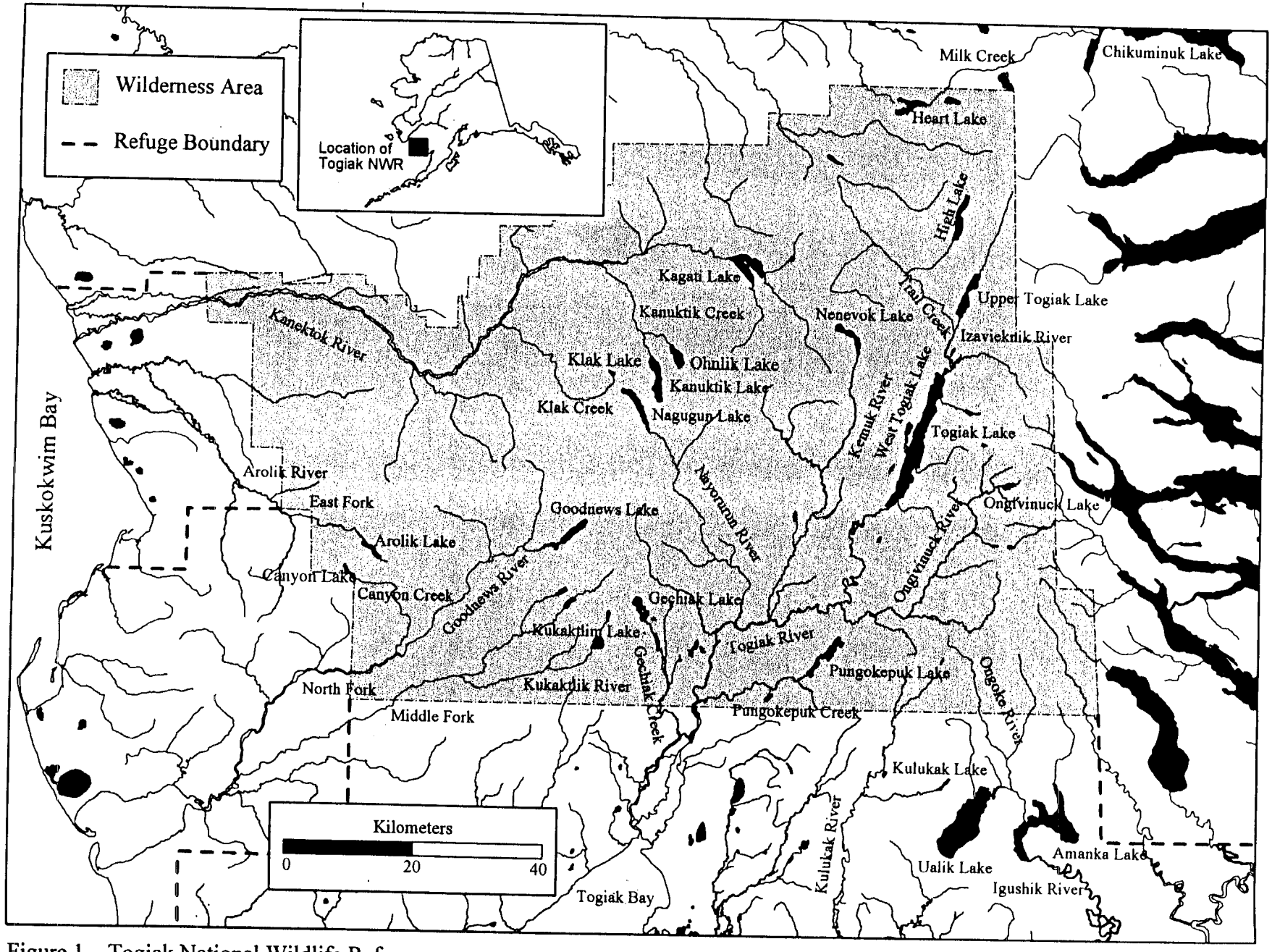

Figure 1. Togiak National Wildlife Refuge.

Table 1. Physical characteristics of Togiak National Wildlife Refuge lakes.

Lake	Length of lake (km)	(miles)	Width of lake (km)	(miles)	Surface area (hectares)	(acres)	Distance above sea level (m)	(feet)	Maximum depth (m)	(feet)
Amanka Lake	16.3	10.1	2.7	1.7	3369	8324.8	11.6	38.1	unknown	unknown
Arolik Lake	3.7	2.3	0.6	0.4	195	481.8	134	439.7	54.2	177.8
Canyon Lake	3.4	2.1	0.5	0.3	120	296.5	147.2	483.0	46	150.9
Gechiak Lake	4	2.5	1.6	1.0	438	1082.3	101	331.4	22	72.2
Goodnews Lake	7.2	4.5	1	0.6	310	766.0	122	400.3	39.6	129.9
Heart Lake	5.1	3.2	1.5	0.9	537.9	1329.2	431.6	1416.1	50.3	165.0
High Lake	7.6	4.7	1	0.6	627	1549.3	261.5	858.0	56.4	185.0
Kagati Lake	4.8	3.0	1.1	0.7	1004	2480.9	274	899.0	51	167.3
Kanuktik Lake	6.4	4.0	1.4	0.9	667	1648.2	350	1148.4	38	124.7
Klak Lake	1.9	1.2	1	0.6	69	170.5	320.3	1050.9	unknown	unknown
Kukaktlim Lake	1.9	1.2	2.4	1.5	259	640.0	121.9	400.0	3.5	11.5
Kulukak Lake	2.3	1.4	0.3	0.2	87.5	216.2	90	295.3	21	68.9
Nagugun Lake	8	5.0	0.8	0.5	509	1257.7	285	935.1	58	190.3
Nenevok Lake	4.8	3.0	0.8	0.5	246	607.9	350.5	1150.0	32	105.0
Ohnlik Lake	3.1	1.9	1	0.6	144	355.8	305	1000.7	42.7	140.1
Ongivinuck Lake	2	1.2	0.8	0.5	79	195.2	163	534.8	12.2	40.0
Pungokepuk Lake	10.5	6.5	1.6	1.0	604	1492.5	68.9	226.1	16.5	54.1
Togiak Lake	22.5	14.0	1.6	1.0	3884	9597.4	67.4	221.1	142.6	467.9
Ualik Lake	12.3	7.6	4.2	2.6	4031	9960.6	16.6	54.5	unknown	unknown
Upper Togiak Lake	7.2	4.5	1	0.6	738	1823.6	92	301.9	67	219.8
West Togiak Lake	3.1	1.9	1.2	0.7	171	422.5	24.4	80.1	24.4	80.1

Table 2. Mean water quality measurements of Togiak National Wildlife Refuge lakes, 1984-1990.

		Temperature (degrees celsius)	pH	Dissolved oxygen (ppm)	Conductivity (uS/cm)	Secchi (m)	Acidity (mg/l)	Alkalinity (mg/l)	Carbon dioxide (mg/l)	Hardness (mg/l)
Amanka Lake	06/06/84	6.3	7.0	12.3	32.9	7.5				
Arolik Lake	06/06/84	4.3	7.0	13.0	35.6	9				
	08/28/88	10.9	7.9		42.3	11.6	0	90.7	10	14.7
Canyon Lake	06/06/84	4.4	7.2	12.9	30.7	8.5				
	08/25/88	9.9	7.5		38.3	10.1	0	3.1	10	13.4
Gechiak Lake	06/06/84	8.2	6.8	11.6	25.9	8				
	10/30/86	2.5	8.5	10.3	23.5	7.9	4.56	20.52	10	17.1
	08/20/88	10	7.4		30.7	4.3	0	68.3	8.3	11.3
Goodnews Lake	06/06/84	6.6	6.7	12.4	27.3	8				
	07/20/86	7.4	8.0	11.4		7.8	0	20.4	5	17
	10/30/86	3.7	8.2	10.6	27.9	10	6.84	20.52	10	17.1
Heart Lake	06/06/84	5.1	7.5	12.0	88.7	12				
	07/13/87	7.4	7.5	10.1	81.4	6.5	0	51	13.3	45.3
High Lake	06/04/84	5.0	7.2	11.6	55.1	12.5				
	07/13/87	7.4	7.2	9.7	50.8	8.4	0	34	11.7	34
Kagati Lake										
Kagati Arm	06/04/84	4.1	7.1	11.9	43.3	8				
Pegati Arm	06/04/84	3.9	7.0	12.0	41.7	8.5				
	06/30/86	5.6	7	14		7.3	0	42.5	5	17
	10/30/86	3.0	8.4	10.8	41.5	8.8	2.28	20.52	10	34.2
Kagati Lake	10/22/87	5.0	7.2	14.4	42.7					
Mid lake	07/07/89	7.7	7.2							
Kagati Arm	07/16/89	7.0	7.0							
Kagati Arm	07/27/89	9.0	7.6	33.2						
	08/03/89	8.8								
	08/18/89	10.7	8.4							
	08/24/89	10.7	7.1							
	08/29/89	9.8	7.4	27.3						
	09/06/89	8.7	7.2	30.2						
Kanuktik Lake	06/04/84	4.5	7.0	11.4	30.8	12.0				
	10/30/86	3.6	8.3	10.2	22.9	13.4	6.84	13.68	10	17.1
	08/03/88					12.0	0	30	9.2	16.5
Klak Lake	06/04/84	5.5	6.9	10.8	50.4	8.5				
Kukaktlim Lake	06/06/84	15.0	6.8	9.7	23.7	3.5				
Kulukak Lake	06/06/84	8.4	7.1	12.1	34.2	7				
	07/24/88	12.3	6.9	10.5	30.7	8.9	0.0	56.7	10.0	34.0
Nagugun Lake	06/04/84	3.8	6.9	12.6	24.2	8				
	10/30/86	3.2	8.4	9.9	23.9	9.75	6.84	13.68	10	17.1
	07/29/88					7.1	0	51	10	17
Nenevok Lake	10/30/86	1.8	8.5	11.3	65.8	9.4	4.56	20.5	10	34.2
	07/08/87	4.4	7.5	11.2	53.2	3.1	0.0	28.3	16.7	56.7
Ohnlik Lake	08/07/88					12.2	0.0	10.3	15.0	20.3
Ongivinuck Lake	08/10/87	10.0	6.5	10.4	58.2	6.8	0.0	34.0	10.0	34.0
Pungokepuk Lake	06/06/84	12.5	7.2	9.6	55.0	4				
	10/30/86	2.0	8.6	11.5	51.4	4.26	6.84	27.36	10	
	07/14/88	14.8	7.9	8.5	56.7	4.5	0.0	68.0	5.0	34.0
Togiak Lake	06/04/84	2.7	7.5	12.7	60.7	7.5				
	08/27/86		7.5	10.6				34.0	5	51
	10/30/86	5					5.7	27.36	10	34.8
Ualik Lake	06/06/84	5.9	7.0	12.6	29.6	8.5				
Upper Togiak Lake	06/04/84	4.7	7.5	11.8	70.5	12				
	10/30/86	4.2	8.1	11.0	62.8	7.6	6.84	34.2	10	51.3
	08/04/87	6.5	7.4	11.3	53.0	3.6	0.0	34.0	15.0	113.3
West Togiak Lake	07/01/87	6.6	6.9	11.2		10.6	0.0	23.8	14.0	37.4

Table 3. Discharge measurements for Togiak National Wildlife Refuge lakes.

Lake	Location	Width m	Area m^2	Velocity m/sec	Discharge m^3 /sec
Amanka Lake	NA				
Arolik Lake	inlet	6.45	1.11	0.05	0.06
	outlet	11.50	1.92	0.31	0.59
Canyon Lake	inlet	6.21	1.91	0.50	0.95
	outlet	7.82	2.32	0.69	1.59
Gechiak Lake	northeast inlet	4.36	0.76	0.50	0.38
	north inlet	10.93	4.75	0.70	3.33
Goodnews Lake	NA				
Heart Lake	outlet	3.20	1.38	0.75	1.03
High Lake	inlet	9.00	4.73	0.40	1.88
	outlet	10.37	5.93	0.56	3.29
Kagati Lake	NA				
Kanuktik Lake	inlet	7.34	1.01	0.14	0.14
Klak Lake	NA				
Kukaktlim Lake	NA				
Kulukak Lake	inlet	6.04	0.71	0.50	0.36
	outlet	16.90	6.47	0.14	0.91
Nagugun Lake	outlet	9.35	2.45	0.76	1.87
Nenevok Lake	NA				
Ohnlik Lake	inlet	5.00	0.73	0.41	0.30
	outlet	21.01	2.17	0.35	0.76
Ongivinuck Lake	north inlet	5.49	2.24	3.87	0.86
	south inlet	10.37	4.43	5.34	2.26
	west outlet	17.14	10.05	3.34	3.80
Pungokepuk Lake	southeast inlet	8.14	1.65	0.34	0.56
Togiak Lake	NA				
Ualik Lake	NA				
Upper Togiak Lake	east inlet	15.25			
	main inlet	21.35			
	northwest inlet	10.98			
	outlet	45.75			
West Togiak Lake	inlet	11.29			
	outlet	20.74			

NA = Discharge measurements are not available for these lakes.

Table 4. Number of fish caught per sampling method on Togiak National Wildlife Refuge lakes, 1984-1990.

Lake	Gear Type	Sample Effort (hours)	Char	Arctic Grayling	Lake Trout	Northern Pike	Sculpin	Stickleback	Rainbow Trout	Chinook Salmon	Sockeye Salmon	Coho Salmon	Unidentified Salmon	Whitefish	TOTAL
Amanka Lake	NA														-
Arolik Lake	gill net	25			9										9
Canyon Lake	hook & line	7	8		3									1	12
	gill net	10.25	15		1						13				29
	minnow trap	60.5					41			1	2	70			114
Gechiak Lake	hook & line	3.25	4						1						5
	gill net	45.5	23							1	1				25
	minnow trap	27.5						88				2			90
Goodnews Lake	hook & line	no data	3		15										18
Heart Lake	hook & line	1.5	1		37										38
	gill net	67.75	14		20										34
	minnow trap	116.5			2		9								11
High Lake	gill net	59	21											14	35
	minnow trap	96	29											10	39
Kagati Lake	hook & line	no data	40		758						4	6			808
	gill net	no data	12								9			17	38
	minnow trap	no data	14									24			38
	handpicked	not applicable									239				239
Kanuktik Lake	hook & line	1.5			2										2
	gill net	78	8		6										14
	minnow trap	149.5													-
Klak Lake	NA														-
Kukaktlim Lake	NA														-
Kulukak Lake	hook & line	5	2												2
	gill net	47	25								45			19	89
	minnow trap	139	19				5			5	15	8			52
Nagugun Lake	hook & line	2.5	3												3
	gill net	74.5	43											4	47
	minnow trap	156.5					13			2					15
	handpicked	not applicable	2												2
Nenevok Lake	gill net	19	7		2										9
	minnow trap	201	10		21		14								45
Ohnlik Lake	hook & line	7	2		20										22
	gill net	14			4										4
	minnow trap	20.75									1	1			2
Ongivinuck Lake	hook & line	no data	6												6
	gill net	18	14	1							3			3	21
	minnow trap	214	8					3		72					83
Pungokepuk Lake	hook & line	26.25				14			7		2				23
	gill net	126				30			8		26			29	93
	minnow trap	327					3	311	6		56	1	76		453
Togiak Lake	NA														-
Ualik Lake	NA														-
Upper Togiak Lake	hook & line	no data	3												3
	gill net	no data	4												4
	minnow trap	138	116				15								131
West Togiak Lake	gill net	22	35			1								9	45
	minnow trap	no data	10				2	14							26
TOTALS	hook & line	54	72		835	14			8		6	6			934
	gill net	606	218	1	42	31			8	1	97			96	494
	minnow trap	1529.75	206		23		102	416	6	80	74	106	76	10	1099
	handpicked	not applicable	2								239				241
	TOTAL	2306.25	501	1	900	45	102	416	22	81	416	112	76	106	2778

NA = Fisheries data are not available for these lakes.

Table 5. Lengths and weights of fish species caught in Togiak National Wildlife Refuge lakes, 1984-1990.

		Char				Arctic grayling				Rainbow trout				Lake trout				Northern pike				Coho Salmon			Sockeye Salmon			Whitefish			
		Males	Females	Length	Weight	Males	Females	Length	Weight	Males	Females	Length	Weight	Males	Females	Length	Weight	Males	Females	Length	Weight	Males	Females	Length	Males	Females	Length	Males	Females	Length	Weight
Amanka Lake	NA																														
Arolik Lake	Avg.													1	5	400	862														
	Range															368-447	500-1700														
Canyon Lake	Avg.	5	10	437	879									--	1	471	1190														
	Range			375-520	630-1400											450-510	980-1530														
Gechiak Lake	Avg.	11	8	427	851																										
	Range			298-560	250-1790																										
Goodnews Lake	Avg.	--	--	536	--									--	--	504	--														
	Range			497-607	--											435-614	--														
Heart Lake	Avg.	4	10	418	1034									11	9	457	1200														
	Range			180-556	250-2400											398-709	700-4150														
High Lake	Avg.	11	10	327	351																										
	Range			260-455	150-850																										
Kagati Lake	Avg	--	--	508	2339									13	21	423	658					4	2	833	74	165	513	--	--	420	
	Range			341-755	750-4750											380-671	700-3850							675-1000			400-650			381-445	
Kanuktik Lake	Avg	3	3	490	1429									3	2	457	1233														
	Range			400-585	795-2000											405-740	660-4800														
Klak Lake	NA																														
Kukaktlim Lake	NA																														
Kulukak Lake	Avg	11	13	255	325																										
	Range			120-485	10-1310																										
Nagugun Lake	Avg	29	17	350	462																									6	12	137	19
	Range			275-479	10-1240																										120-155	10-70
Nenevok Lake	Avg	4	3	426	1036																									2	2	137	13
	Range			280-565	250-2150									1	1	533	1713														135-141	10-15
Ohnlik Lake	Avg.	--	--	472	1110											515-550	1650-1775														
	Range			388-555	650-1570									3	1	410	732														
Ongivinuck Lake	Avg.	6	14	382	668	1	--	253	225							360-454	500-1100														
	Range			307-447	300-1050			253	225																						
Pungokepuk Lake	Avg.									2	5	574	2148					11	14	487	881							2	1	328	392
	Range											464-640	1300-2950							164-580	30-1700									290-403	250-625
Togiak Lake	NA																								5	4	581	9	17	468	1245
Ualik Lake	NA																										447-630			385-528	700-1950
Upper Togiak Lake	Avg.	--	7	332	409																										
	Range			310-355	340-510																										
West Togiak Lake	Avg.	2	1	417	726																							4	5	405	622
	Range			330-532	375-2075																									375-426	575-650

NA = Fisheries data are not available for these lakes

Table 6. Fish stomach contents and frequency of occurrence, Togiak Refuge Lakes.

Food Item	Arolik Lake lake trout n = 6	Heart Lake char n = 14	Heart Lake lake trout n = 20	High Lake char n = 21	Kagati Lake lake trout n = 22	Ongivinuck Lake char n = 20	West Togiak Lake char n = 23	Total
Insects								
Tricoptera					1			1
Diptera					8			8
Plecoptera					16			16
Hymenoptera					3			3
Lepidoptera					2			2
Coleoptera					1			1
Nematodes				1			9	10
Flukes			1	6		3		10
Tapeworms	2				5			7
Flies	1					1		2
Mosquitos						1		1
Unknown		8	12	7		3	1	31
Mollusks								
Clams					2	4		6
Snails & mollusks	6	13	16	5	5	12	2	59
Fish								
Stickleback			1		4	2		7
Sculpin			1					1
whitefish				1				1
Lake trout			1					1
Eggs				1		1		2
Fish remains	1			2	13	2	4	22
Other								
Debris							8	8
Leech					9			9
Small mammal					1			1
Totals	10	21	33	23	70	29	24	210

Table 7. Number of individual plankton species found in Togiak National Wildlife Refuge lake water samples.

						Number per liter of original water									
						Crustacea									
						Copepoda		Cladocera		Immature	Eubranchiopoda	Protozoa	Rotifera		
Lake	Location	Date	Depth of Plankton tow (feet)	Volume Filtered (liters)	Total Number of Organisms in Sample	*Diaptomus*	*Tropocyclops prasimus*	*Daphnia*	*Eubosmina hagmanni*	*Nauplius*	*Eubranchiopod*	*Volvox*	*Asplanchna*	*Unidentified*	TOTAL
Amanka Lake	NA														-
Arolik Lake	NA														-
Canyon Lake	NA														-
Gechiak Lake	unknown	10/30/86	45	147.47	35	1.55	1.24	0.93	3.41						-
Goodnews Lake	inlet	07/24/86	45	147.47	4	0.08		0.08	0.16				3.72		10.85
	middle	07/24/86	45	147.47	150	2.18		6.86	5.09	1.25					0.32
	outlet	07/24/86	45	147.47	8	0.32	0.10	0.21		0.10			0.21		15.59
	lower lake	07/25/86	45	147.47	18	0.34		0.68		0.91			0.10		0.83
	middle	10/30/86	45	147.47	96	13.11	1.64	14.09	1.64	0.98			0.11		2.04
Heart Lake	north bay	07/13/87	65	213	2127	8.99	20.73	0.29	0.55	10.04					31.46
	main lake	07/13/87	65	213	752	4.15	9.19	0.38	0.81	1.47					40.60
	south bay	07/13/87	65	213	1207	6.74	10.38	0.59	0.89	5.96					16.00
High Lake	inlet	07/31/87	45	147.47	88		5.80	0.23	2.56	1.62					24.56
	middle	07/31/87	45	147.47	380	0.12	18.60	1.74	23.00	0.70					10.21
	outlet	07/31/87	45	147.47	157		6.97		9.04	0.11					44.16
Kagati Lake	mid Kagati	06/30/86	45	147.47	293	4.21	10.99	1.34	1.22	0.12					16.12
	outlet	06/30/86	45	147.47	124	2.91	7.88	0.37	0.37	0.09					17.88
	Kagati inlet	07/14/86	45	147.47	12	0.42	0.42	0.42							11.62
	Pegati inlet	08/19/86	45	147.47	98	3.19	1.49	1.27	3.93	0.53					1.26
	outlet	08/19/86	20	65.54	12		1.45	0.87	0.58	0.58					10.41
	outlet	08/19/86	45	147.47	27	0.26	1.16	0.65	0.39	1.03					3.48
	Kagati inlet	08/20/86	45	147.47	62	2.86	2.34	5.46	5.20	0.26					3.49
	mid Kagati	08/20/86	45	147.47	80	1.34	1.95	3.54	2.93						16.12
	Atmugiak Cr.	08/30/86	45	147.47	73	1.33	1.52	0.28	0.05	0.28					9.76
	Kagati inlet	09/10/86	45	147.47	82	0.39	2.62	6.03	1.44	0.13					3.46
	mid Kagati	09/10/86	45	147.47	132	5.03	3.97	3.84	3.84	0.66			0.13		10.74
	outlet	09/10/86	45	147.47	127	2.77	2.88	3.21	4.98	0.22			0.13		17.47
	Pegati inlet	09/10/86	45	147.47	82	2.56	1.92	2.04	3.19	0.64					14.06
	outlet	10/30/86	45	147.47	92	10.53	2.16	12.38	3.41				0.13		10.48
	mid Kagati	07/23/87	45	147.47	600	0.17	17.80	0.20	1.00	0.90					28.48
	outlet	07/23/87	45	147.47	124	0.31	4.81	1.02	0.45	1.07	0.19				20.07
	mid Kagati	08/11/87	45	147.47	221	3.18	3.31	0.78	4.81	1.20					7.85
	outlet	08/11/87	30	98.31	90	0.28	3.03	1.99	2.09	0.85	0.28				13.28
	mid Kagati	08/19/87	45	147.47	831	0.64	12.58	2.98	5.38	0.84	5.38				8.52
	outlet	08/19/87	45	147.47	244	0.50	1.37	1.52	4.38	1.05					27.80
	mid Kagati	08/26/87	45	147.47	294	4.43	6.18	0.94	4.02	1.57					8.82
	outlet	08/26/87	45	147.47	427	1.33	3.44	6.11	2.50	10.34					17.14
Kanuktik Lake	unknown	10/30/86	45	147.47	61	1.25	13.83	2.83	1.25						23.72
Klak Lake	NA														19.16
Kukaktlim Lake	NA														-
Kulukak Lake	NA														-
Nagugun Lake	unknown	10/30/86	45	147.47	208	13.00	8.06	4.68	5.46	0.52					-
Nenevok Lake	unknown	10/30/86	45	147.47	155	1.12	17.17	1.44	4.97				22.36		54.08
	north end	07/08/87	60	196.62	387		6.87	0.02	0.07				0.16		24.86
	middle	07/08/87	60	196.62	395		7.59		1.39						6.96
	south end	07/08/87	60	196.62	122		3.59		0.51	1.07			0.04		8.98
Ohnlik Lake	NA														5.21
Ongivinuck Lake	east end	08/10/87	30	98.31	272		1.79	0.27	1.07	1.07	9.94		10.20		-
	middle	08/10/87	38	124.53	790		3.42	0.50	3.49	0.35	4.91		43.58		24.34
	west end	08/10/87	35	114.7	648		5.77	1.22	1.95	1.55	21.08		21.15		56.25
Pungokepuk Lake	unknown	10/30/86	20	65.54	8		0.56	0.56				0.56	1.71	1.14	52.72
Togiak Lake	inlet	08/14/86	45	147.47	50	0.73	1.87	0.08	1.06	0.32					4.53
	middle	08/18/86	45	147.47	123	1.40	7.57	0.81	4.42	0.12					4.06
	outlet	08/18/86	45	147.47	90	1.67	6.57	0.90	0.65	0.90					14.32
	middle	06/15/87	45	147.47	60	0.54	1.72		0.05	0.41			0.90		11.59
	outlet	06/15/87	20	65.54	27	0.92	1.28	0.27							2.72
	outlet	06/15/87	30	98.31	21	0.42	0.42	0.05		0.21					2.47
	middle	07/06/87	45	147.47	84	0.18	2.34	0.13		1.00					1.10
	outlet	07/06/87	25	81.93	398	5.26	23.83	2.13	0.58	0.90					3.65
	middle	07/20/87	45	147.47	144	0.14	5.65	0.18	0.05	0.50					32.70
	outlet	07/20/87	25	81.93	120	0.08	8.41	0.23		0.46					6.52
	middle	07/28/87	45	147.47	708	5.35	27.23	0.43	0.80	9.71					9.18
	outlet	07/28/87	25	81.93	249	2.94	14.04	0.31		8.04					43.52
	middle	08/21/87	45	147.47	144	3.19	6.12	4.34	0.52	4.21					25.33
	outlet	08/21/87	25	81.93	9	0.24	1.39	0.24							18.38
	middle	09/11/87	45	147.47	161	1.72	1.82	2.58	0.25	1.77			0.24		2.11
	outlet	09/11/87	21	68.81	36	1.49	0.24	0.74	0.24	1.73					8.14
Ualik Lake	NA														4.44
Upper Togiak Lake	unknown	10/30/86	45	147.47	123	4.29	8.21	3.93	5.00						-
	north end	08/03/87	45	147.47	490		12.64	0.42	3.92	1.08			0.54		21.97
	middle	08/03/87	45	147.47	300		7.51	0.54	4.48				0.77		18.83
	south end	08/03/87	45	147.47	392		9.60	0.40	2.31				1.04		13.57
West Togiak Lake	north end	06/14/87	60	196.62	13				0.30				0.63		12.94
	middle	06/14/87	60	196.62	0										0.30
	south end	06/14/87	30	98.31	0										0.00
TOTALS				9483.87	15937	132.15	387.03	113.55	148.10	81.42	41.78	0.56	107.85	1.14	0.00 1013.58

NA = Plankton data is not available for these lakes

Table 8. Pyloric caeca and gill raker counts for char sampled in Togiak National Wildlife Refuge lakes.

	Heart Lake		High Lake		Ongivinuck Lake		Upper Togiak Lake		West Togiak Lake	
	Pyloric Caeca	Gill Rakers	Pyloric Caeca	Gill Rakers	Pyloric Caeca	Gill Rakers	Pyloric Caeca	Gill Rakers	Pyloric Caeca	Gill Rakers
1	35	26	24	21	41	22	34	18		8
2	38	24	25	20	42	24	38	24		20
3	40	17	26	20	42	20	42	20		20
4	42	24	26	22	45	20	42	24		21
5	43	22	26	22	45	24	45	24		22
6	44	28	27	25	45	21	47	19		22
7	44	25	28	20	46	19	48	19		24
8	44	25	28	22	48	23				30
9	47	26	29	20	48	22				30
10	52	22	29	19	49	24			19	27
11	52	22	30	23	49	23			23	20
12	52	25	30	21	50	19			23	20
13	56	23	30	20	51	22			24	22
14	57	24	30	21	52	20			25	26
15			31	19	52	18			26	21
16			32	25	52	22			28	22
17			33	24	53	24			31	22
18			34	21	54	22			37	22
19			34	22	56	22			38	20
20			36	24	60	20			39	23
21			38	22					39	22
22									41	23
23									47	19
Average	46	24	30	22	49	22	42	21	31	22
Species	Arctic char		Dolly Varden		Arctic char		Arctic char		Dolly Varden	

DISCUSSION

All data collected from the lake survey project provides a base that should be built upon. The data collected so far has been used primarily in the Togiak Refuge Fisheries management Plan.

Bathymetric Mapping

Triangulation was found to be the most accurate method in locating transect points on the lakes. This method requires a clear enlargement of a topographical map or aerial photo for best results. Note taking during the graphing will result in more accurate drawing of contour lines. The use of shoreline landmarks to develop sonar transects was the preferred method. Larger lakes had a lower density of transects, requiring more extrapolation and interpolation. Sonar mapping was not performed on Amanka, Klak, Kukaktlim, and Ualik Lakes as these lakes were only surveyed for water quality during the preliminary sampling performed in 1984.

Almost all of the lakes surveyed are similar in structure but have a wide range of maximum depths. Each lake has a steep dropoff near the perimeter that gradually decreases until the bottom is reached. The inlet, outlet, or both, ends of the lakes are shallower with a more gradual drop in depth. These lake bottom characteristics are similar to other southwest Alaska lakes surveyed by Bosch, Coggins, and Minard (1995).

Spawning Areas

Sockeye salmon production in a drainage relates to the availability of suitable spawning habitat, juvenile rearing areas, overwinter habitat, lake productivity, and other factors. Surveys described habitat of the lake's near shore area and concentrations of spawning sockeye salmon. Each lake surveyed was found to have some suitable spawning habitat although quantifying habitat was not attempted. Concentrations of sockeye salmon were documented around the perimeter of most lakes. The criteria used to classify spawning density (small, medium, large) is difficult to apply due to survey timing.

Shoreline Substrate and Land Characteristics

One of the objectives of substrate description is to quantify the lake bed for fish spawning habitat (Hamilton and Bergersen 1984). The textural composition of the substrate influences survival and emergence of the embryos of many fish species and production of aquatic plants and invertebrates. Substrate type is critical to salmonids and trout which do not guard their eggs but cover them and leave. A wide range of substrate types from silt to large boulders were found in each of the Togiak Refuge lakes. Shoreline substrate types were classified as small in nearly all areas of observed sockeye salmon spawning. Combining of the shoreline substrate types and

bathymetric contours will provide some clue to the quantity of available sockeye spawning habitat.

Water Quality of Major Lakes

For most lakes, the baseline water quality data collected was the first of such information to be documented. However, eight Kuskokwim Bay lakes (Arolik, Canyon, Goodnews, Kagati, Kanuktik, Klak, Kukaktlim, and Ohnlik Lakes) were sampled in 1975 and 1976 by the Alaska Department of Fish and Game (Alt 1977) and surface waters in the Togiak River basin were sampled in 1980 and 1982 by the U.S. Geological Survey (Kernodle, Squires, and Childers 1983).

Results from the pH, dissolved oxygen, conductivity, and alkalinity found in this Togiak National Wildlife Refuge lake survey study are similar to results found by Kernodle, Squires, and Childers (1983) in the Togiak River basin, which they state as indicating excellent overall water quality.

All Togiak Refuge baseline water quality parameters are typical of oligotrophic lakes as described in Wetzel (1975). These lakes have excellent water quality and no measurements are out of the ordinary.

The range of pH found in natural waters ranges between 6 and 8 for the majority of lakes (Love 1965), and are often slightly basic due to the presence of carbonates and bicarbonates. All pH measurement on Togiak Refuge lakes are in this range.

A strong acidity indicates the water's degree of corrosiveness (Wetzel 1975). Most of the Togiak Refuge lakes sampled had no acidity and are not corrosive and had a wide range of alkalinity (3.1-90.7 mg/l).

Levels of hardness in all refuge lakes sampled are well below levels classified as undesirable in Hach (1987). Togiak Refuge lakes have a wide range of hardness (13.4 to 113.3 mg/l) and fall in the categories of soft water (0-60 mg/l) and moderately hard water (61-120 mg/l) as listed in Love (1965).

Conductivity in Togiak Refuge lakes is very low and shows the waters as being very pure and as having few dissolved solids (Love 1965, Hamilton and Bergersen 1984 and Hach 1987).

Dissolved oxygen is one of the most important analyses in determining the quality of natural waters (Hach 1987). Dissolved oxygen concentrations below 3.0 mg/l are generally considered harmful to aquatic life, but requirements vary according to species, temperature, life stage, activity, and concentrations of dissolved substrates in the water (Hamilton and Bergersen 1984).

Dissolved oxygen found in Togiak Refuge lakes was above 3.0 mg/l and suitable for fish and other organisms.

Carbon dioxide (of which high concentrations are corrosive and have been known to kill fish (Hach 1987)) is present in all surface waters in amounts generally less than 10 mg/l, although higher concentrations are not uncommon. Carbon dioxide measurements for all lakes sampled in the Togiak Refuge fell within this range and are not corrosive waters.

Stream Discharge

The discharge values for inlet and outlet streams were calculated based on the water level at the time of the survey. No maximum or minimum discharge rates were determined.

Age, Weight, and Length of Fish Species

For most lakes, the baseline fisheries data collected was the first of such information to be documented. Eight Kuskokwim Bay lakes (Arolik, Canyon, Goodnews, Kagati, Kanuktik, Klak, Kukaktlim, and Ohnlik Lakes) were sampled in 1975 and 1976 by the Alaska Department of Fish and Game and fisheries data is available for comparison (Alt 1977). However, sample sizes were small for most species.

Gill raker and pyloric caeca counts showed both Arctic char and Dolly Varden to be present in Togiak Refuge lakes at the time of sampling. Some of the counts were slightly outside of the ranges of gill rakers and pyloric caeca listed in Morrow (1980), but we are still confident in the species identification.

Plankton Sampling

Each of the plankton species and or genera present in the lakes surveyed belong to orders that are found in a wide variety of habitats and play an important part in the food chain. The two Copepoda and two Cladocera species are known to be of great importance as food for young and adult fish, and for immature and mature insects (Pennak 1989). The Protozoa and Rotifera species present serve as food for Cladocera and Copepoda species, and small fish.

Plankton are important components of aquatic systems, serving as indicators of water quality (Needham and Needham 1962). Chemical conditions play a part in determining the taxonomic nature of the plankton, and the species composition is used to classify the water as polluted or free from pollution and suggest the quantities of naturally occurring substances (Lind 1979). Aquatic insects sampled in 1980 and 1982 in the Togiak River basin (Diptera, Chironomidae, Ephemeroptera, Plecoptera, and Tricoptera) are commonly associated with clean, well-

oxygenated, cool streams (Kernodle, Squires and Childers 1983). The number of taxa at all sites reflects the well-diversified composition of invertebrates and indicates the general overall good health of the streams surveyed.

RECOMMENDATIONS

This report summarizes the baseline physical, biological, and chemical characteristics of 21 lakes throughout the Togiak National Wildlife Refuge over a six year period. The data collected and presented was gathered with limited resources and time. Future surveys should be intensified on the biota (fishery, insect, plankton) density and abundance, and on quantifying the habitats available for spawning and rearing of the various species present. Other recommendations include: additional and more detailed sonar transects at the three larger lakes (Togiak, Goodnews and Kanektok) to determine the length of shelves or submerged islands that were noted on the marked transects; quantifying numbers of sockeye salmon spawning in particular areas of the lakes; conducting surveys on major tributaries into the lakes; determining the density of redds; scale pattern analysis to establish stock separation in the system; growth of juveniles; size structure of smolts in the lake and tributaries; and lake productivity.

Future work should fill in gaps in the data. Information regarding contour mapping, spawning areas, shoreline substrate , land characteristics, water quality, stream discharge, fishery, and plankton sampling should be completed.

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Appendix A. U.S. Department of the Interior, Geological Survey Discharge Measurement Notes, Form 9-275-F.

9-275-F
(Rev. 10-81)

UNITED STATES
DEPARTMENT OF THE INTERIOR
GEOLOGICAL SURVEY
WATER RESOURCES DIVISION

Meas. No. . . . . . .
Comp. by. . . . . . .

Sta. No. . . . . DISCHARGE MEASUREMENT NOTES Checked by . . . . .

. . . .

Date . . . ., 19 . . . . . . Party . . . .
Width . . . . Area . . . . Vel. . . . . G. H. . . . . Disch. . . . .
Method . . . . . . No. secs. . . . . . G. H. change. . . . . . in . . . . . hrs. Susp. . . . . . .
Method coef. . . . . . . Hor. angle coef. . . . . . Susp. coef. . . . . . Meter No. . . . . . .
Type of meter . . . . Date rated . . . . Tag checked . . . .
Meter . . . . ft. above bottom of wt. Spin before meas. . . . . after . . . .
Meas. plots. . . . . % diff. from. . . . . rating. Levels obtained. . . . .

GAGE READINGS					
Time		Inside	ADR	Graphic	Outside
. . . .	. . . .	. . . .	. . . .	. . . .	. . . .
. . . .	. . . .	. . . .	. . . .	. . . .	. . . .
. . . .	. . . .	. . . .	. . . .	. . . .	. . . .
. . . .	. . . .	. . . .	. . . .	. . . .	. . . .
. . . .	. . . .	. . . .	. . . .	. . . .	. . . .
. . . .	. . . .	. . . .	. . . .	. . . .	. . . .
. . . .	. . . .	. . . .	. . . .	. . . .	. . . .
Weighted M.G.H.		. . . .	. . . .	. . . .	. . . .
G. H. correction		. . . .	. . . .	. . . .	. . . .
Correct M.G.H.		. . . .	. . . .	. . . .	. . . .

WATER QUALITY MEASUREMENTS
No . . . . . . Yes. . . . . . Time . . . . . .
Samples Collected
No . . . . . . Yes. . . . . . Time . . . . . .
Method Used
EDI . . . . . EWI . . . . . Other. . . . . .

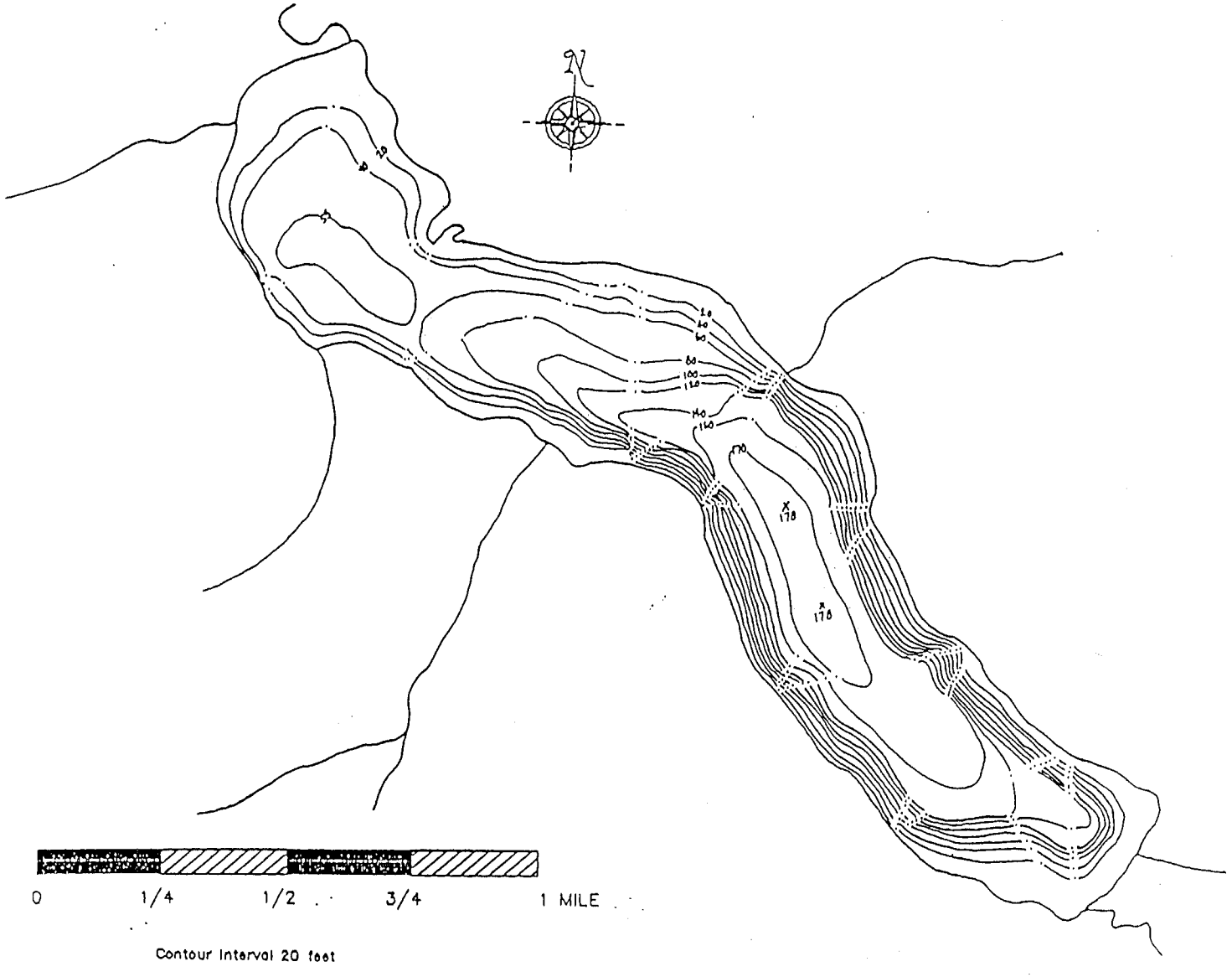
SEDIMENT SAMPLES
No . . . . . . Yes. . . . . . Time . . . . . .
Method Used
EDI . . . . . EWI . . . . . Other. . . . . .

BIOLOGICAL SAMPLES
Yes. . . . . Time . . . .
No . . . . Type . . . .

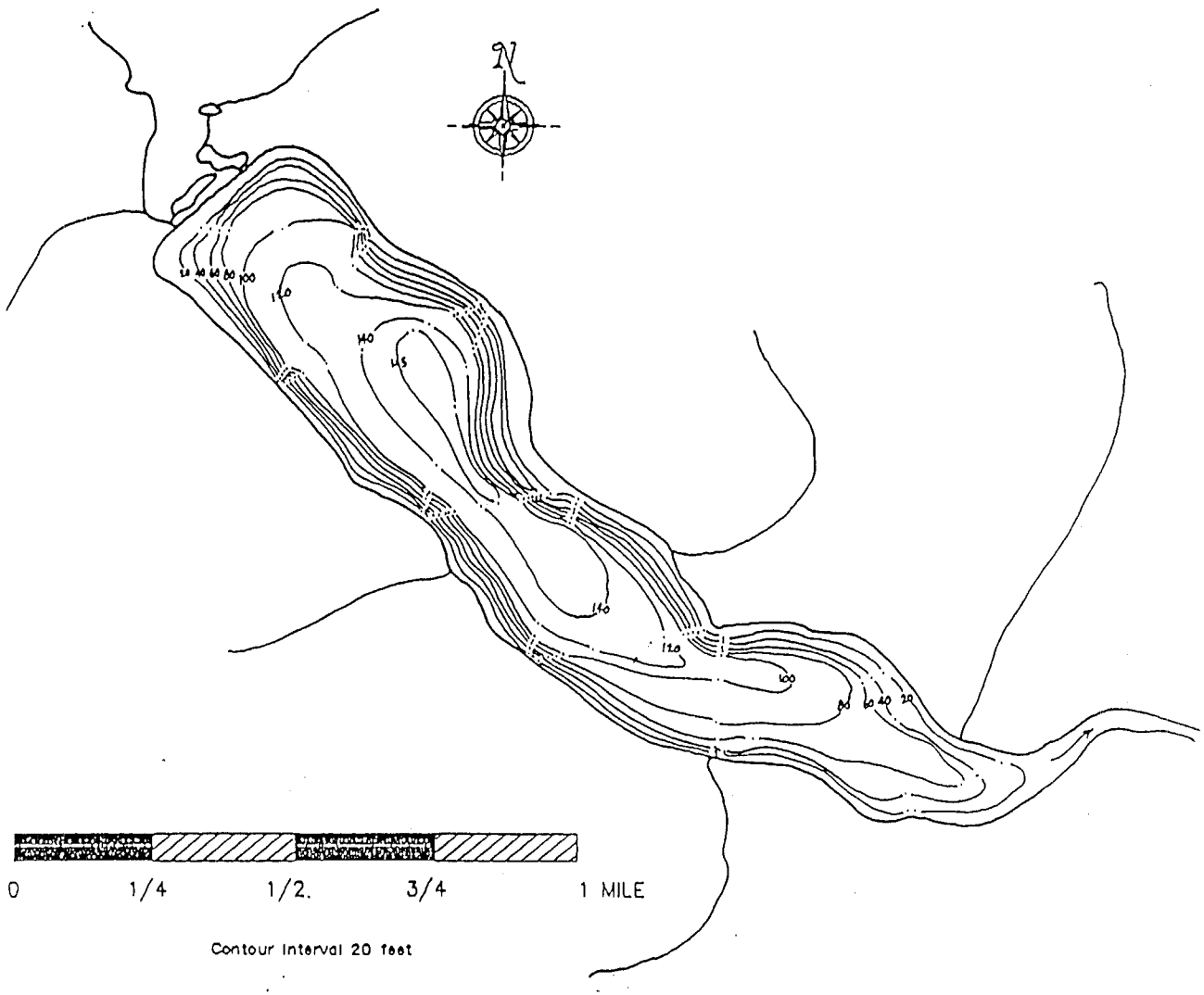
Check bar. chain found . . . . changed to . . . . at . . . .
Wading, cable, ice, boat, upstr., downstr., side bridge. . . . . feet, mile, above, below gage.
Measurement rated excellent (2%), good (5%), fair (8%), poor (over 8%); based on the following cond:
Flow . . . .
Cross section . . . .
Control . . . .
Gage operating . . . . Weather . . . .
Intake/Orifice cleaned . . . . . . Air . . . . . . °C@ . . . . . Water . . . . . . °C@ . . . . . .
Record removed . . . . Extreme Indicator: Max. . . . . Min. . . . .
Manometer N_2 Pressure Tank . . . . Feed . . . . Bbl rate . . . . per min.
CSG checked . . . . Stick reading . . . .
Observer . . . .
HWM . . . . outside, in well
Remarks . . . .
. . . .
. . . .
G.H. of zero flow . . . . ft. Sheet No. . . . . of . . . . sheets

River at—

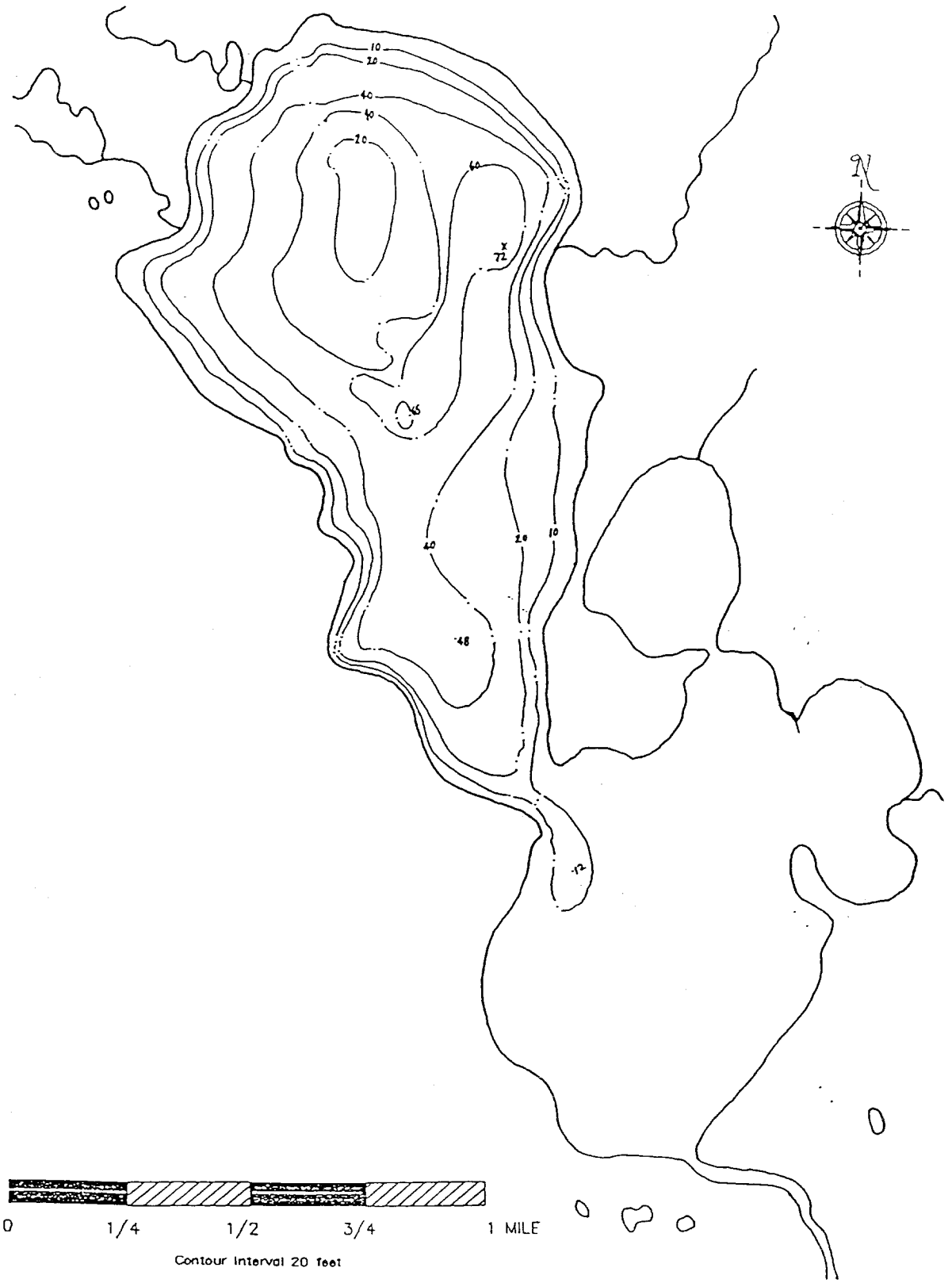
Angle coef.	Dist. from initial point	Width	Depth	Observation depth	Revolutions	Time in seconds	VELOCITY At point	VELOCITY Mean in vertical	Adjusted for hor. angle or	Area	Discharge



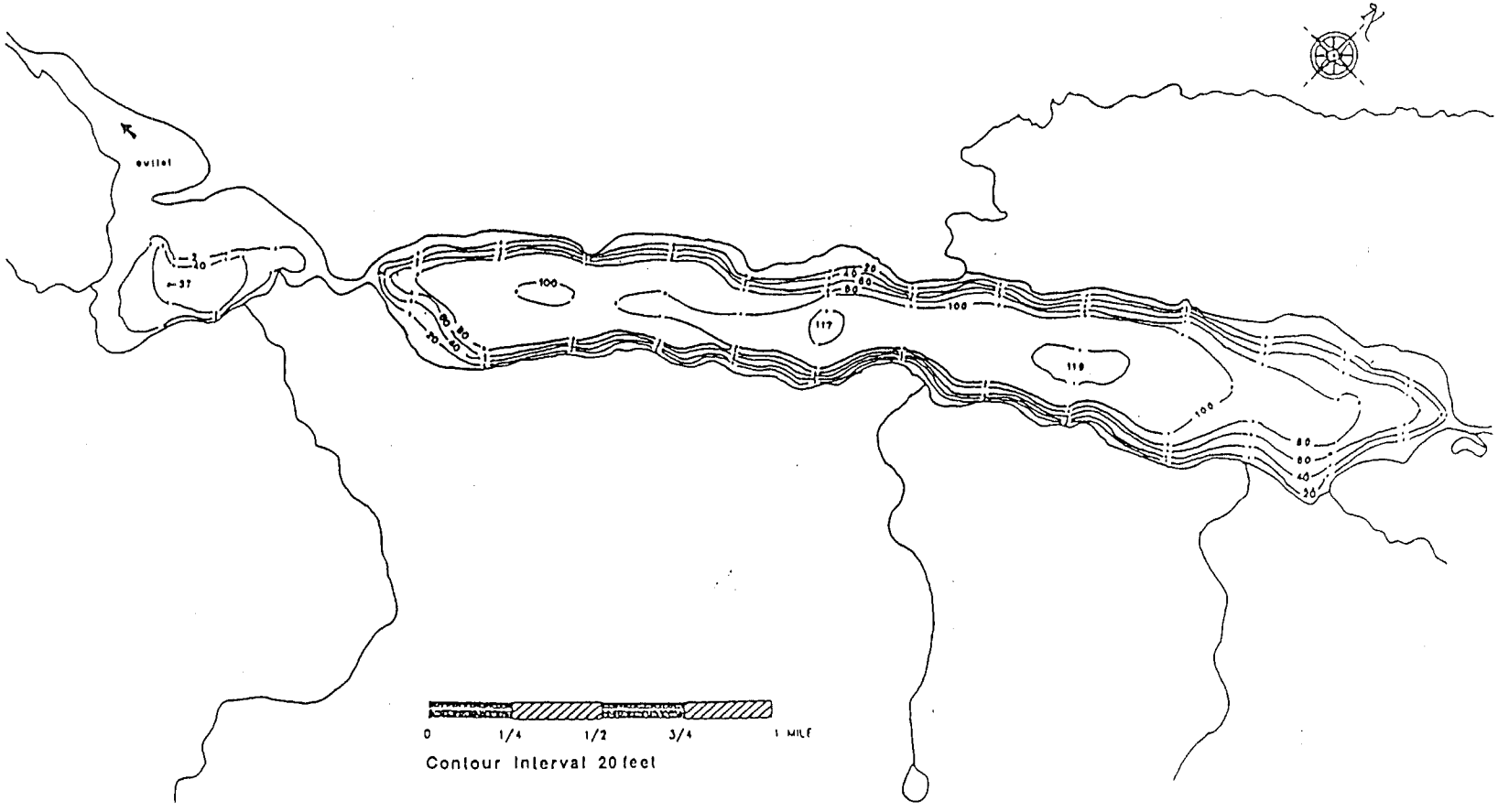
Appendix B1. Bathymetric map of Arolik Lake.



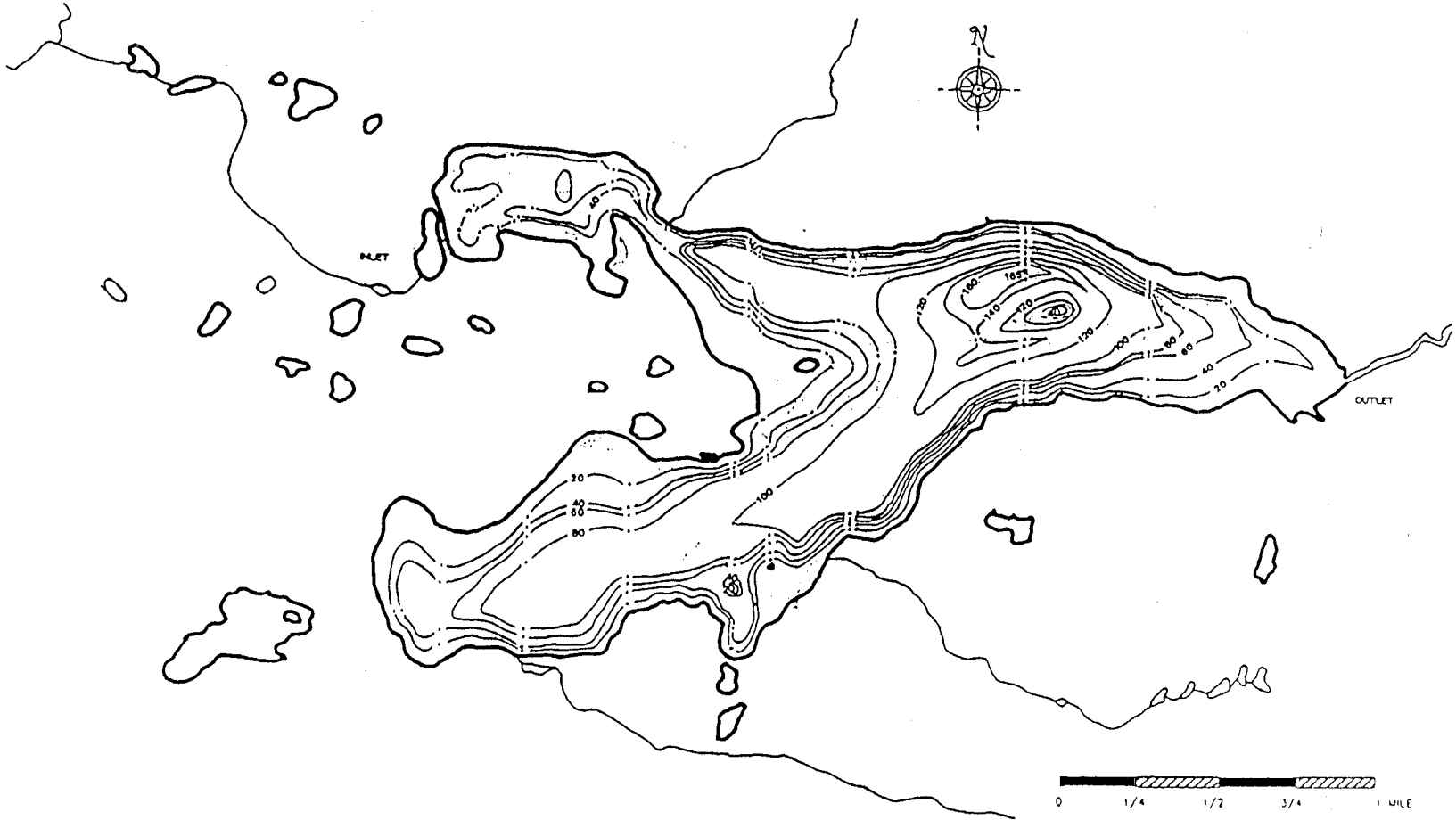
Appendix B2. Bathymetric map of Canyon Lake.



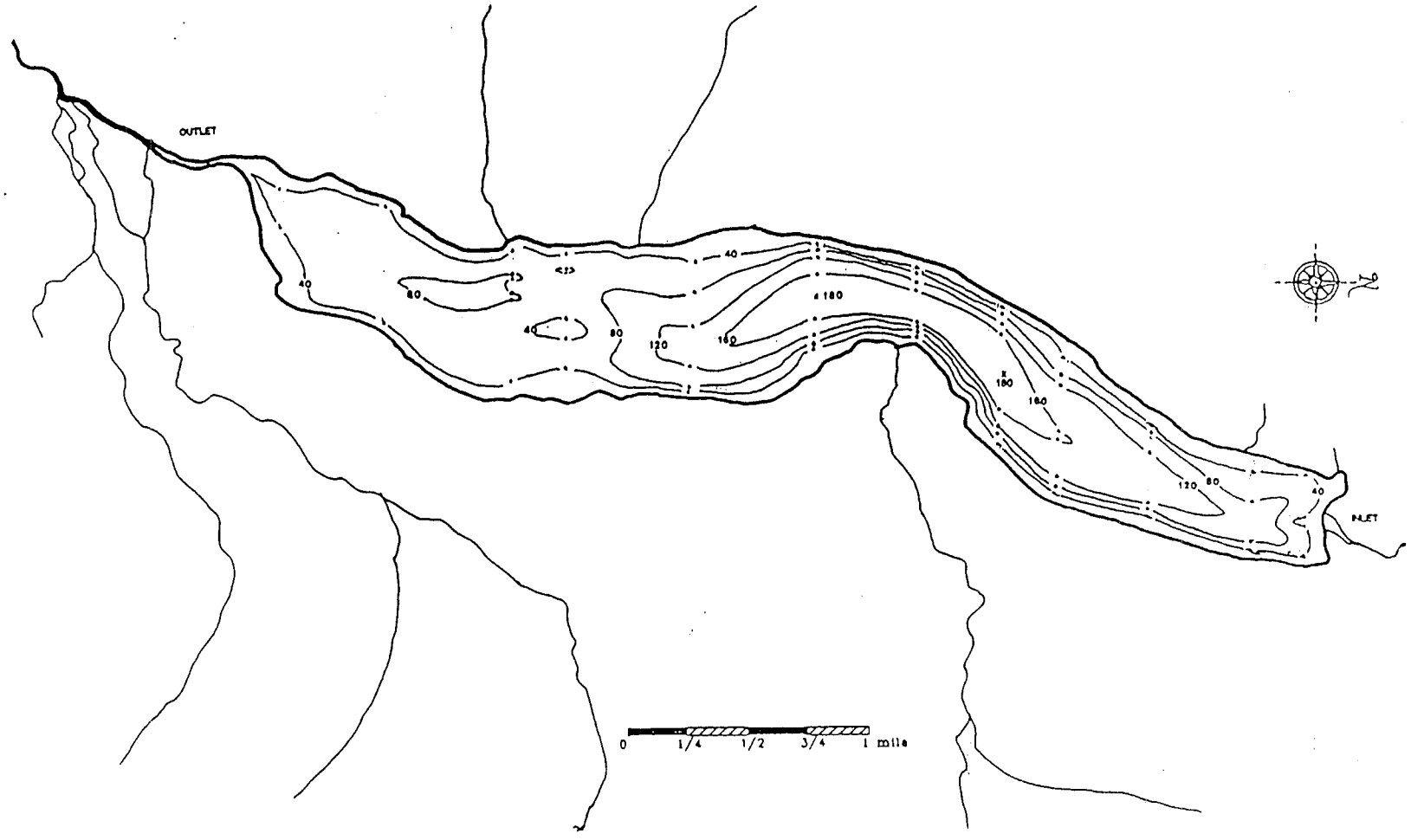
Appendix B3. Bathymetric map of Gechiak Lake.



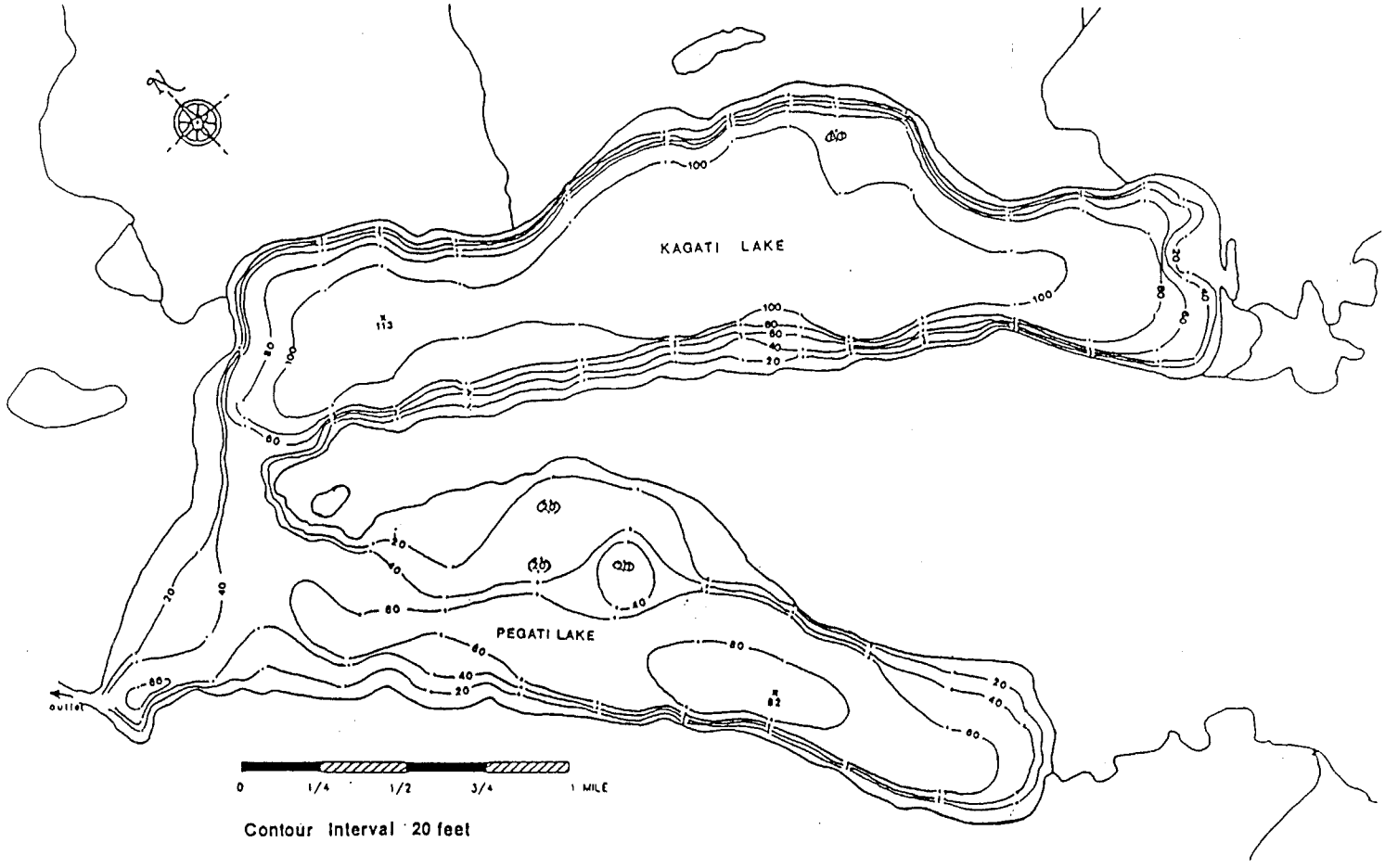
Appendix B4. Bathymetric map of Goodnews Lake.



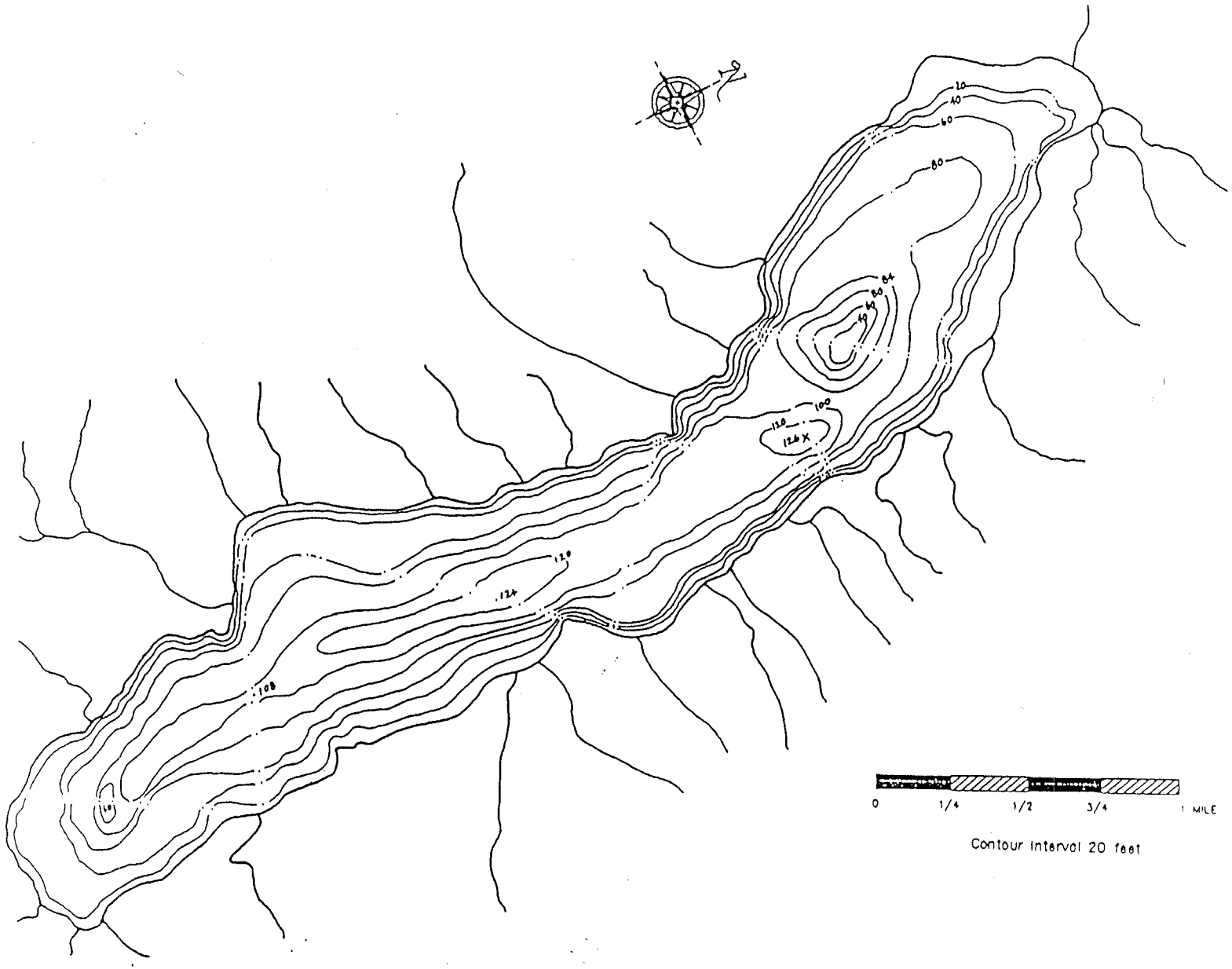
Appendix B5. Bathymetric map of Heart Lake.



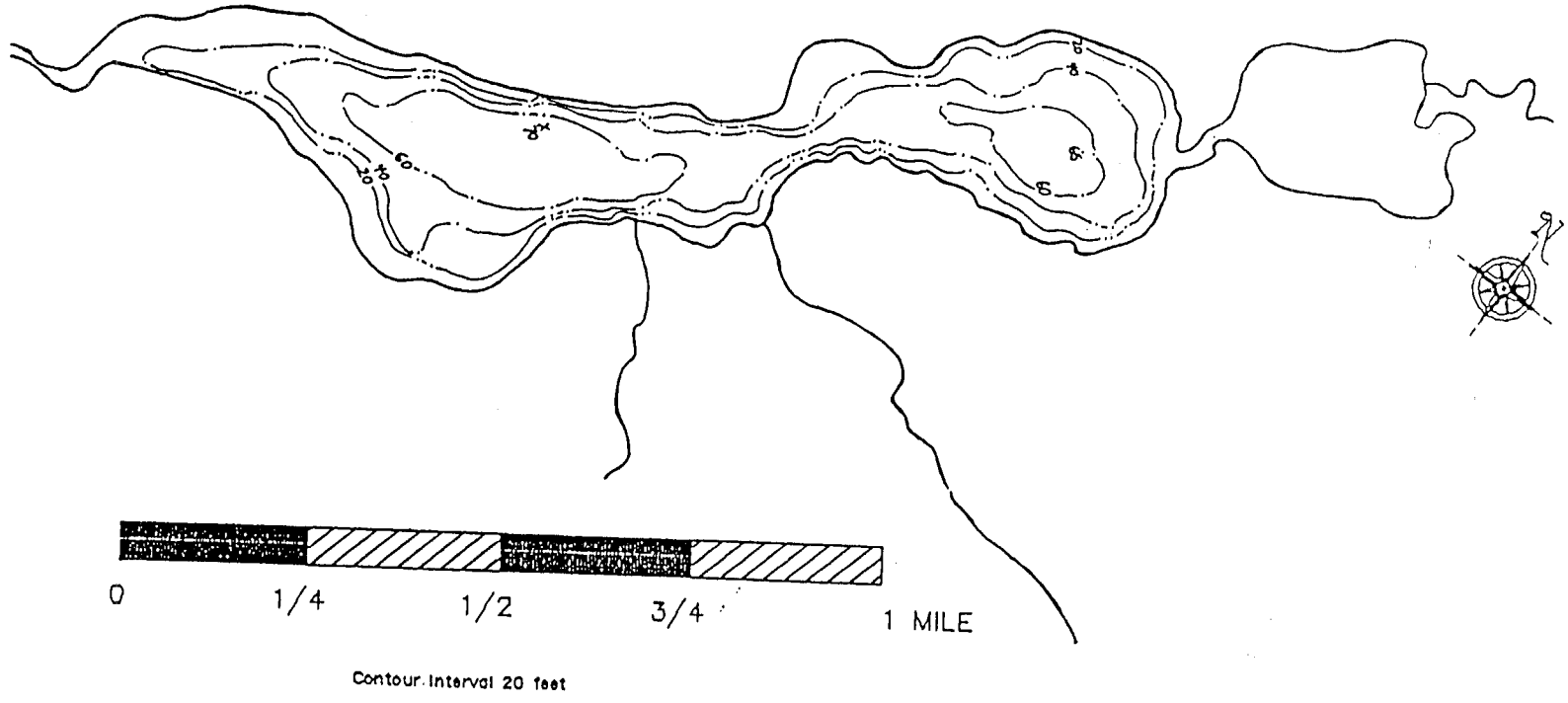
Appendix B6. Bathymetric map of High Lake.



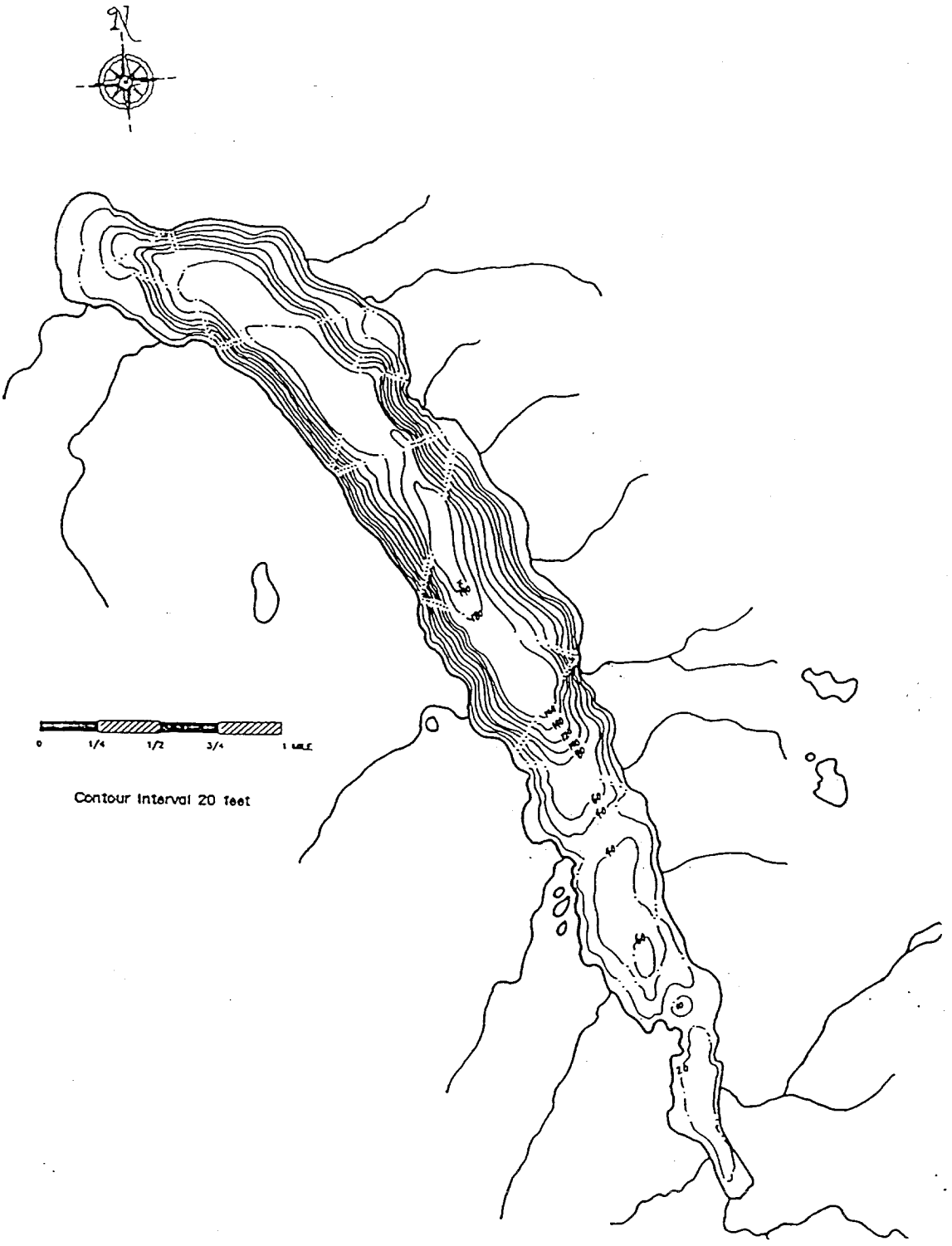
Appendix B7. Bathymetric map of Kagati Lake.



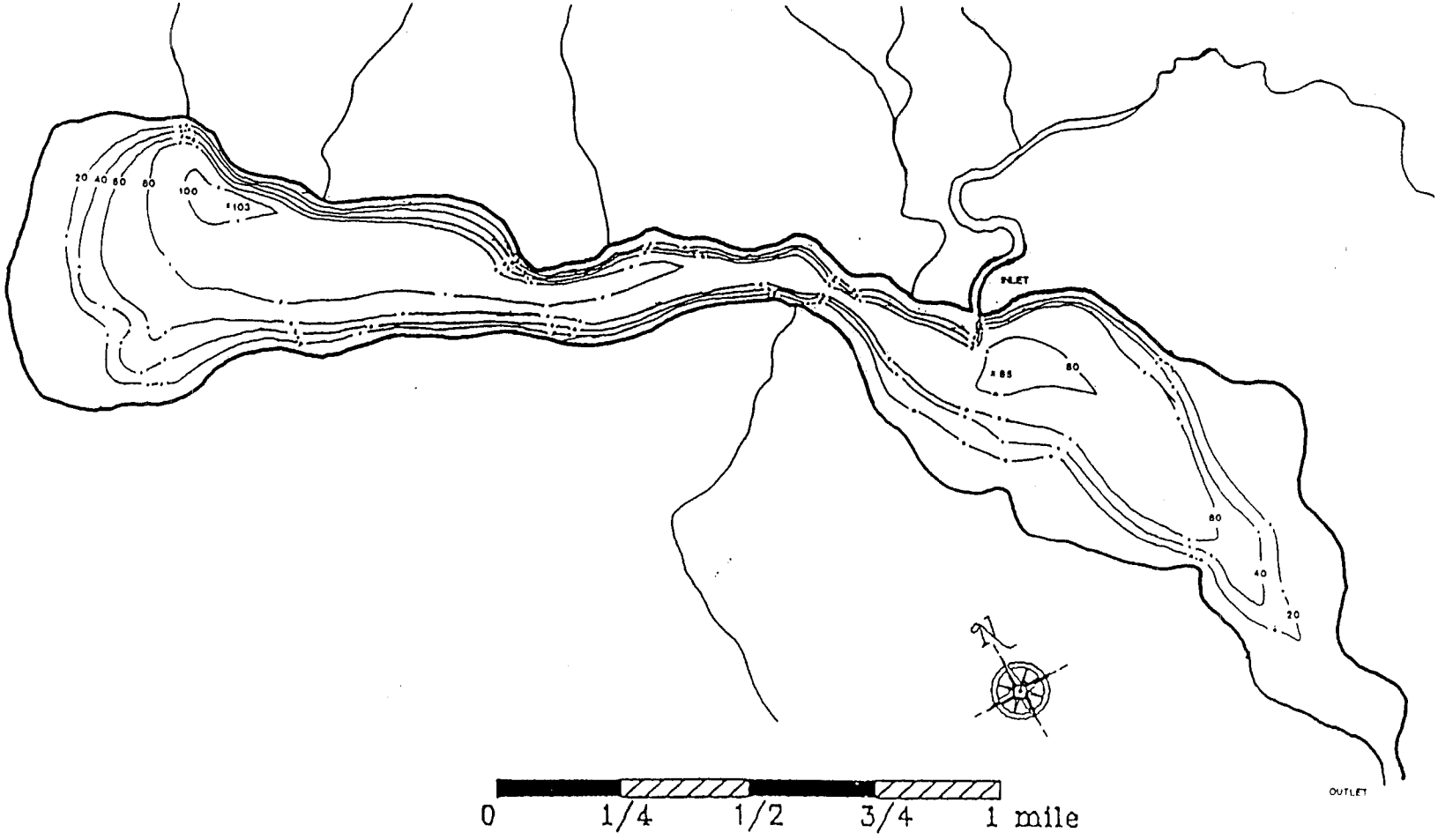
Appendix B8. Bathymetric map of Kanuktik Lake.



Appendix B9. Bathymetric map of Kulukak Lake.

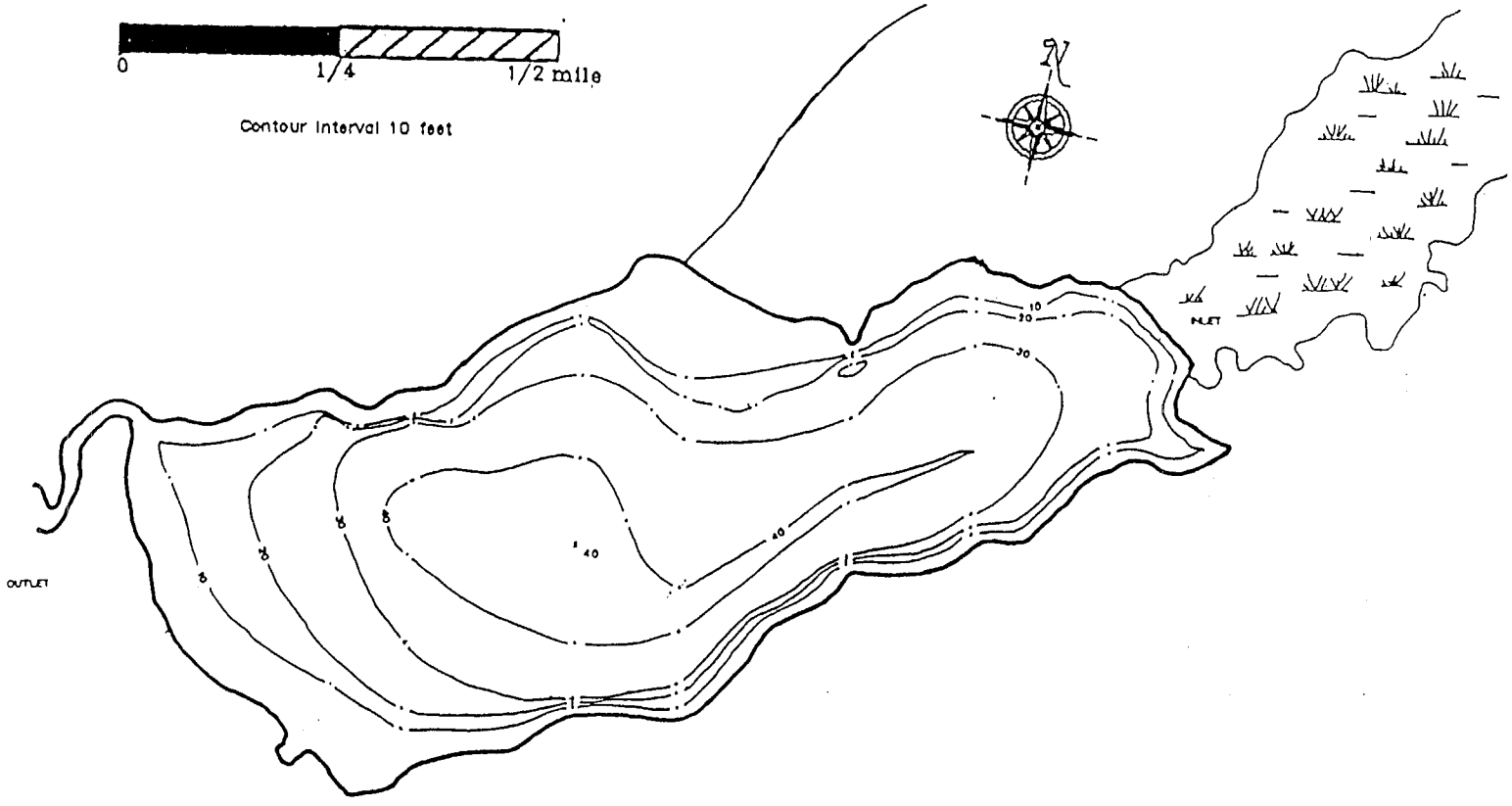


Appendix B10. Bathymetric map of Nagugun Lake.

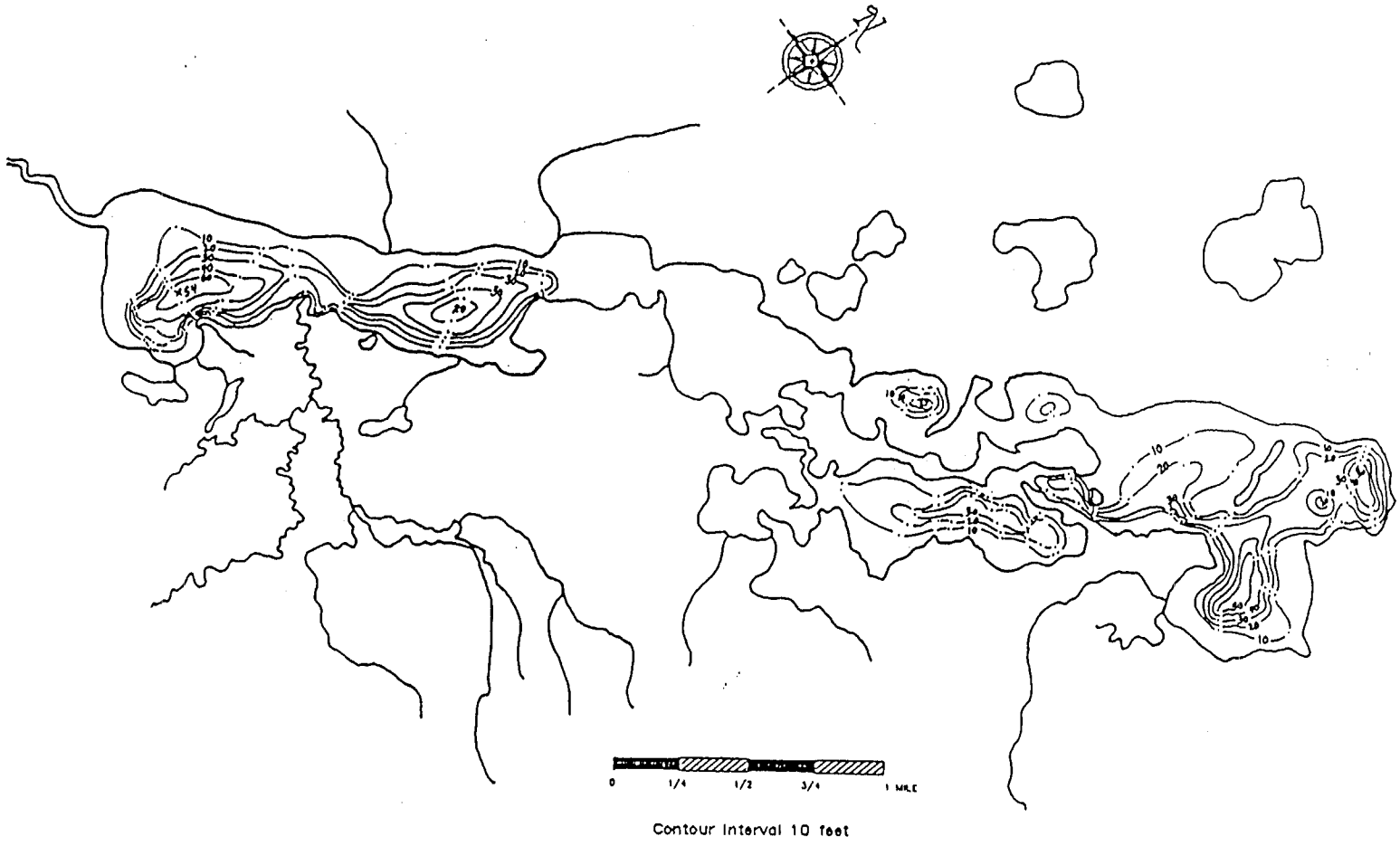


Appendix B11. Bathymetric map of Nenevok Lake.

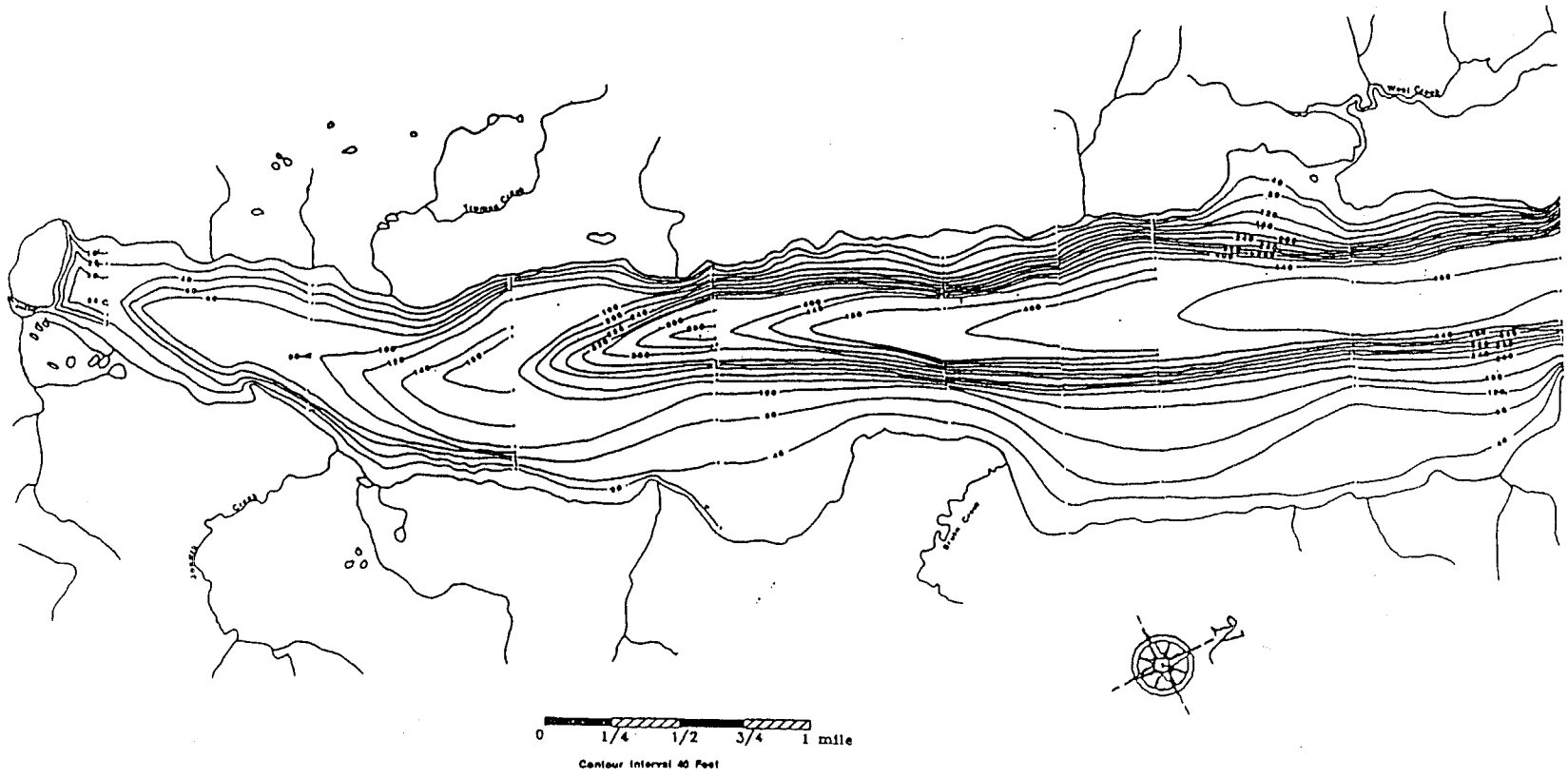
Appendix B12. Bathymetric map of Ohnlik Lake.



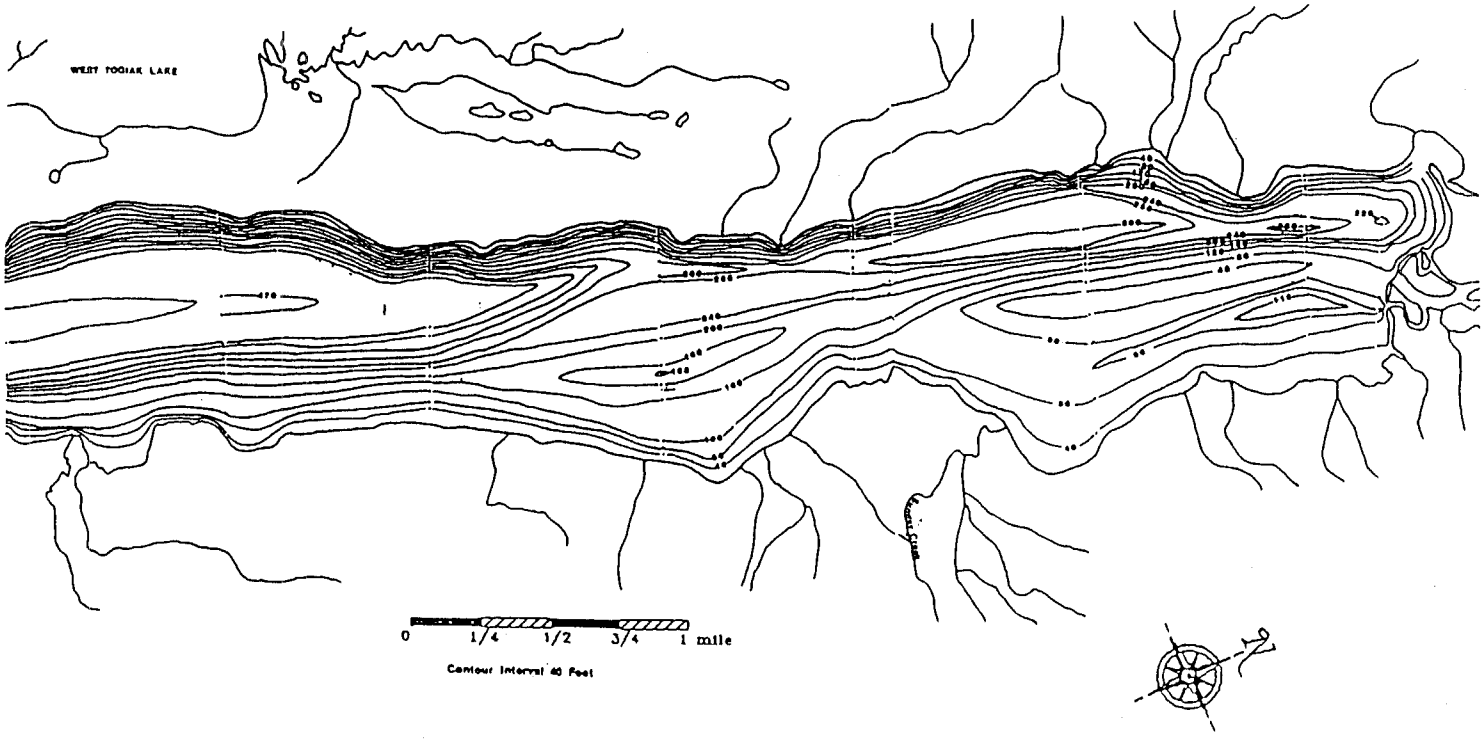
Appendix B13. Bathymetric map of Ongivinuck Lake.



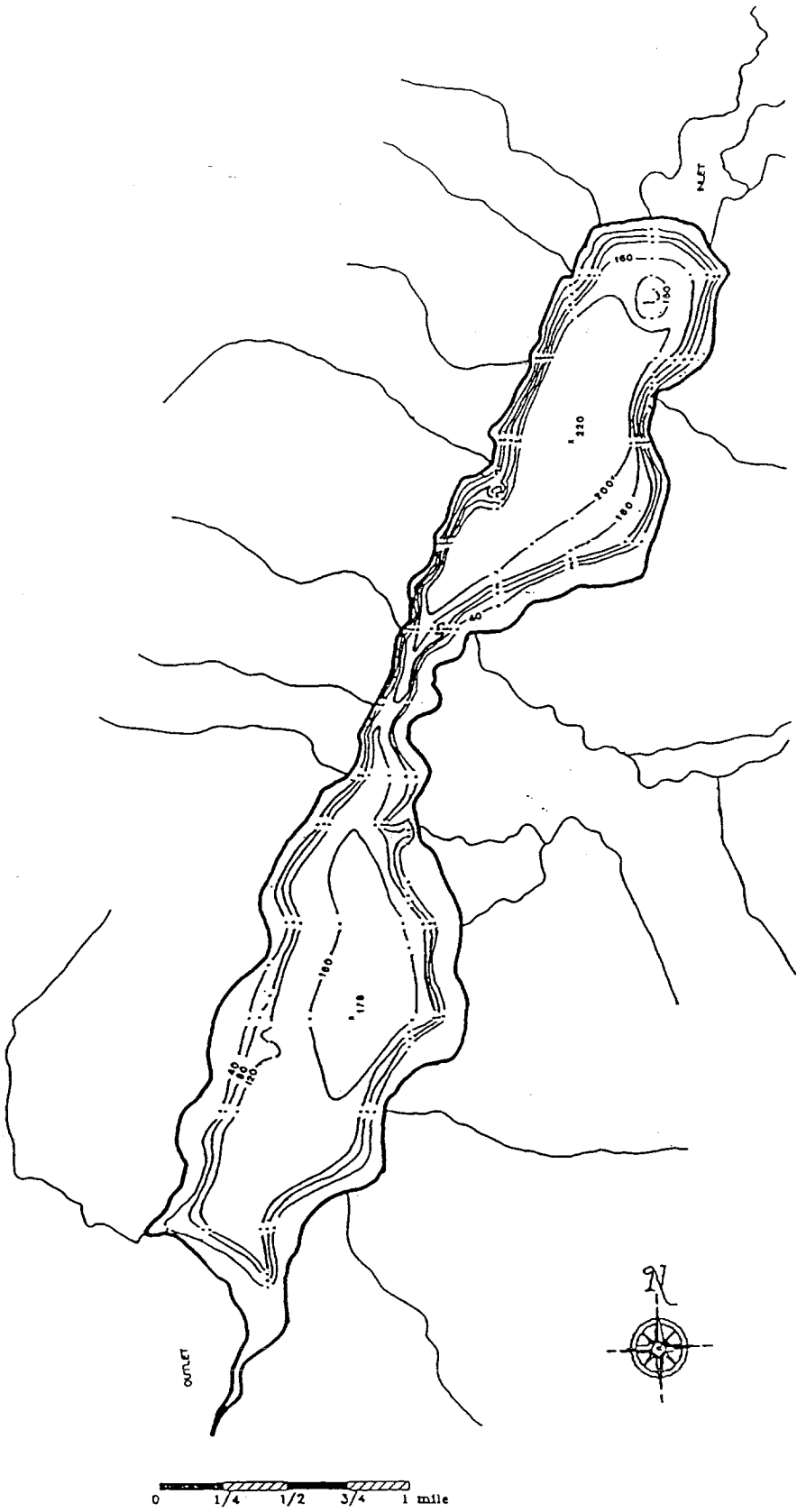
Appendix B14. Bathymetric map of Pungokepuk Lake.



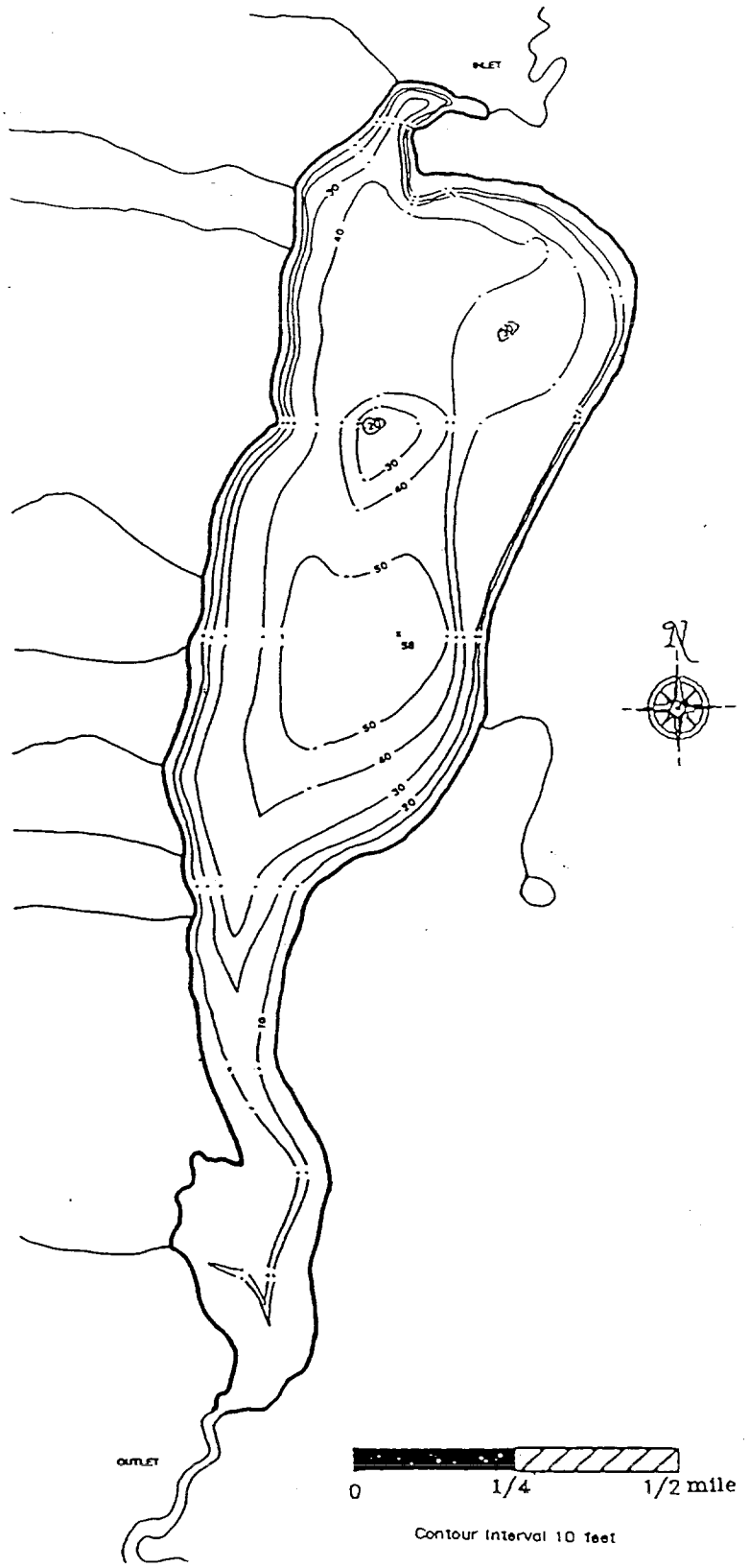
Appendix B15. Bathymetric map of Togiak Lake.



Appendix B15. Bathymetric map of Togiak Lake.



Appendix B16. Bathymetric map of Upper Togiak Lake.



Appendix B17. Bathymetric map of West Togiak Lake.